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FIELD EVALUATION OF THE MODULAR AUGERED-BED HEAT-RECOVERY SOLID--ETC(U)

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TECHNICAL REPORT E-128
May 1978

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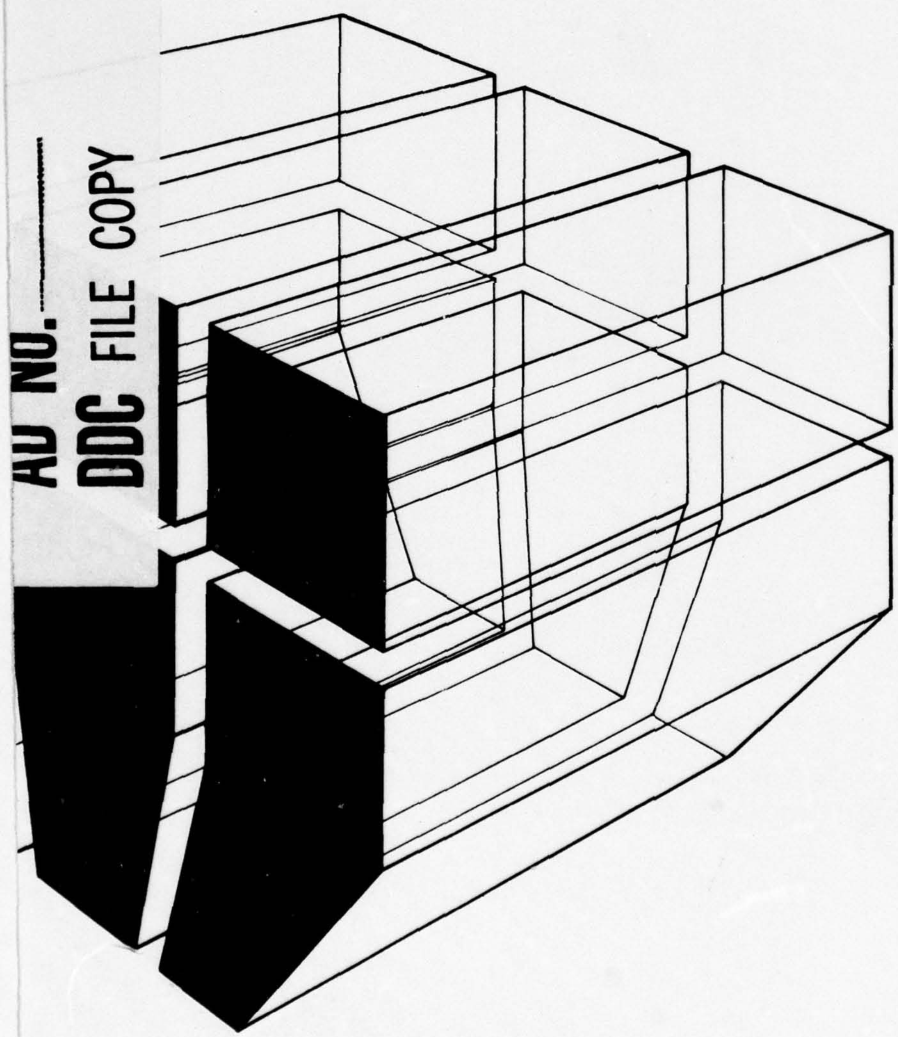

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CERL-TR-E-128	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FIELD EVALUATION OF THE MODULAR AUGERED-BED HEAT-RECOVERY SOLID WASTE INCINERATOR.		5. TYPE OF REPORT & PERIOD COVERED FINAL rept.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) S. A. Hathaway, J. S. Lin A. N. Collishaw		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005 Champaign, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A763734DT09-T1-002
11. CONTROLLING OFFICE NAME AND ADDRESS 63734A		12. REPORT DATE May [redacted]78
		13. NUMBER OF PAGES 56 58p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

augered-bed incinerator
heat exchanger
furnace

ABSTRACT

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a field evaluation of the operating prototype modular (package) augered-bed, heat-recovery, solid-waste incinerator (ABI) conducted on 23-28 May 1977. The ABI tested is a horizontal, cylindrical, cast refractory-faced combustion chamber fitted with a water-cooled auger to convey burning waste. Feeding and ash removal are continuous, and steam is produced in a coiled heat exchanger at the base of the stack

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from water preheated in the auger. The throughput capacity of the furnace is approximately 3.5 tons/hour (3.2 mt/hour), more than three times the capacity of currently marketed modular incinerators.

The report furnishes a detailed description of the system evaluated, a critical appraisal of essential unit operations, and environmental and energy data. The satisfactory performance of the furnace, which is a major innovative aspect of the unit evaluated, indicated that it has potential for Army use. However, because of the unreliability of mechanical auxiliaries, inadequate materials of construction, and poor system configuration, the ABI as it presently exists cannot be recommended for immediate deployment for processing solid waste generated on Army fixed facilities and installations. It was concluded that re-engineering around the furnace using established methods could make a practicable heat-recovery solid-waste incineration system available.

ABSTRACT

FOREWORD

This investigation was performed by the Energy and Habitability Division (EH), U.S. Army Construction Engineering Research Laboratory (CERL), for the Directorate of Facilities Engineering, Office of the Chief of Engineers (OCE) under RDT&E Program 6.37.34, Project 4A763734DT09, "Energy Systems," Task Area T1, "Energy Systems," Work Unit 002, "Demonstration of Use of Packaged Incinerators for Energy Recovery." Mr. B. Wasserman was the OCE Technical Monitor. Mr. S. Hathaway was the CERL Principal Investigator.

Appreciation is extended to the following individuals who assisted in various phases of this investigation: Mr. D. Bingham, Depot Facilities Division, Tooele Army Depot, UT; Mr. J. Miller, Engineering Plans and Services Division, Fort Detrick, MD; Mr. C. Vigh, Urban Studies Section, Jacksonville District, Corps of Engineers; Mr. B. Wasserman, Directorate of Facilities Engineering, OCE, Washington, DC; CPT R. Olfenbuttel, Development Office, Armament Development Test Center, Air Force Systems Command, Tyndall Air Force Base, FL; Mr. P. Stone, Mechanical Systems Division, Naval Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA; and Dr. P. Hopke, Institute for Environmental Studies, University of Illinois at Urbana-Champaign, IL. Administrative support provided by Mr. R. G. Donaghy, Chief of EH, is acknowledged.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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FIELD EVALUATION OF THE MODULAR AUGERED-BED HEAT-RECOVERY SOLID WASTE INCINERATOR

1 INTRODUCTION

Background

A major innovation in solid waste incineration during the past 20 years has been the development of the modular incinerator. These semi-permanent units are predesigned for IIA-type waste,[1] are highway-shippable, have an 8-month procurement time, and are less costly than traditional site-erected furnaces. Because of the size limitations of modular incinerators, their throughput capabilities have been limited to approximately 1 ton/hour (0.9 mt/hour). The modular incinerator most widely used is the controlled-air incinerator, a batch-fed, stationary-bed, horizontal, cylindrical furnace. During the past 5 years, controlled-air systems have been built which use the heat of combustion to produce steam or hot water in a package boiler installed after the incinerator.[2] With development of a relatively inexpensive technology which promises to save costly and scarce conventional fuels, even small communities might afford to incinerate solid waste rather than use valuable land resources for sanitary burial of putrescible materials.[3]

The major drawbacks of the controlled-air incinerator are that (1) feeding and ash removal are on a batch basis, and (2) it has small throughput capability. As shown in Figure 1, the average Army installation, which generates approximately 32 tons/day (29 mt/day) of solid waste, would require two controlled-air incinerators operating in parallel about three shifts/day to process all its waste. A one shift/day operation would require at least five units.

The augered-bed incinerator (ABI) is a recent advance in modular heat-recovery incinerator technology. The unit is a horizontal, refractory-faced cylindrical furnace through which burning waste is moved by a water-cooled auger. Combustion products pass through a heat exchanger above the rear of the furnace to evaporate preheated water from the auger to steam. ABI manufacturers claim that it has a throughput capability of 5 tons/hour (4.5 mt/hour), or five times that of any modular incinerator currently marketed. With one reliably operating unit of this capacity, an Army installation generating up to 35 tons/day (32 mt/day) of solid waste could reduce all its waste to a less biochemically active ash/residue in a one shift/day operation. As shown in Figure 1, the ABI has potential use at more than 50 percent of the major Army installations in CONUS; plants having two or more ABIs could be considered for use at all installations. Moreover, feeding and ash removal are continuous. The potential benefits of using the ABI include reduced waste disposal costs, less environmental impact from landfilling, and conservation of conventional energy resources. At present, the ABI is neither commercial nor fully evaluated.

Objective

The objective of this investigation was to evaluate the performance and operating characteristics of the prototype ABI with respect to its potential use on Army fixed facilities and installations.

Approach

A purchase agreement was made with a contractor, Hoskinson & Associates (H & A), to operate the ABI for 96 continuous hours and to record and report data according to the scope of work summarized in Table 1.

H & A contracted with Technical Services, Inc. (TSI), Jacksonville, FL, to carry out USEPA Method 5[4] point source air pollution emission sampling for particulates.

CERL personnel were on-site during the entire test to record acoustic and incinerator surface temperature data, to collect samples of incinerator ash and residue from air pollution control equipment, to witness operation of the ABI, and to observe the principal contractor's work.

Army personnel with extensive experience in installation facilities engineering were in attendance for 1½ days. Their opinions regarding the practicability of the ABI provided helpful input into the evaluation.

---

[1] S. A. Hathaway and R. J. Dealy, *Technology Evaluation of Army Scale Waste-to-Energy Systems*, Technical Report E-110/ADA042578 (Construction Engineering Research Laboratory [CERL], August 1977).

[2] S. A. Hathaway, *Design Features of Package Incinerator Systems*, Interim Report E-106/ADA040743 (CERL, May 1977).

[3] *Evaluation of Small Modular Incinerators in Municipal Plants* (Ross Hoffman Associates, 1976).

[4] *Federal Register*, Vol 36, No. 228 (November 25, 1971), p 22385.

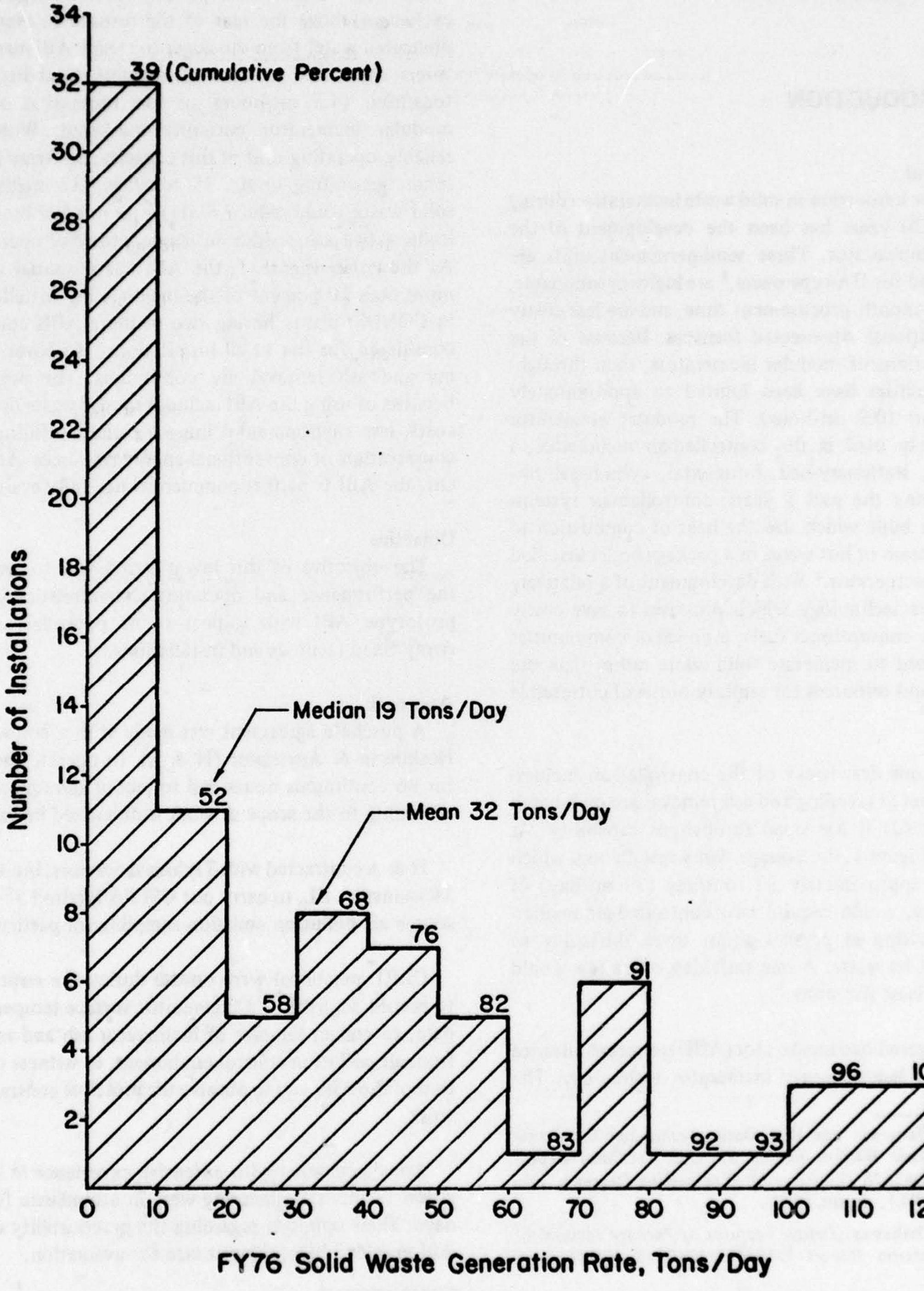

Figure 1. Distribution of solid waste generation rate at major Army installations in CONUS.

Table 1
Summary of Principal Contractor Work for Field Evaluation of the ABI

Item	Summary Description of Principal Contractor Work
General Work Description	Provide all supervision, labor, equipment, instrumentation, utilities, and mixed solid waste required to operate the prototype ABI for 96 continuous hours after initial startup. Furnish a report consisting of all data (including legible copies of log or data sheets) and explanatory comments or information for clarification as appropriate.
Temperatures	Record the temperatures in the combustion chamber and of gases before and after the heat exchanger at startup, every 5 minutes for the first hour, and every half-hour for the remainder of the test. Record temperatures of water to the auger at startup, once every 12 hours, and at the end of the test. Record ambient temperatures at startup, every 4 hours, and at the end of the test.
Steam	Record steam pressure and production rate every 5 minutes for the first hour and every half-hour for the remainder of the test.
Utilities	Record quantities of auxiliary fuel, electricity, and water consumed during the test.
Solid Waste	Weigh all incoming solid waste, ash, scrubber sludge, and bypass wastes. Visually sort, weigh, and determine the volume of two 300-lb (136-kg) incoming solid waste samples daily according to the following categories: paper, cardboard, glass, metal, food waste, yard waste, plastics, rubber, textiles, wood, remainder (categorize as "miscellaneous").
Stack Emissions*	Provide stack particulate emissions samples in accordance with EPA Method 5.

*Required in modification to original contract.

CERL issued a purchase order to the University of Illinois at Urbana-Champaign for the Institute of Environmental Studies to analyze samples of incinerator ash and residue collected by CERL personnel during the test for 30 elements.

The final stage of the investigation was assembly, analysis, and reporting of information from various parts of the field evaluation. This report provides the analyses, conclusions, and recommendations regarding the potential for installation use of the ABI.

Scope

This report furnishes information pertaining to the design and operation of an advanced modular (package) solid waste heat recovery incineration technology having potential use at Army fixed facilities and installations.

Mode of Technology Transfer

This report may be used by OCE to update TM 5-814-4, *Sanitary Engineering, Incinerators*, and related documents as appropriate.

2 FINDINGS

General Description of ABI

Background

The operating prototype ABI which was evaluated is an advanced solid-waste, heat-recovery incineration technology with two experimental forerunners conceived and developed by Mr. G. Hoskinson, Vice President of H & A. In the late 1960s, a 12-in. (305-mm) diameter manure-burning furnace was developed for a Chicago area livestock enterprise. This furnace, which was approximately 10 ft (3.1 m) long, was made by lining with refractory a stack used on Kelly-Hoskinson type controlled-air incinerators and inserting a black-iron screw conveyor to move and mix the material as it burned. This unit was operated only briefly after successfully demonstrating the concept of auger firing. In the early 1970s, a second, larger incinerator was built. This unit was lined with cast refractory and used a black iron auger approximately 28 in. (711 mm) in diameter. The second experimental unit was successfully tested, burning mixed light industrial and residential

trash and fish processing wastes at Wrightsville Beach, NC (1975). It has since been retired. The prototype ABI system was built in 1974-75 and uses a 66-in. (1676-mm) auger to drive the burning waste through the 24-ft (7.3-m)-long cast refractory-lined furnace. A water jacket was retrofitted to the auger late in 1976. By early 1977, this unit had accumulated approximately 2000 hours of intermittent operation, including the destruction of retired postage stamps and outdated credit records. Figure 2 is a general schematic of the prototype ABI evaluated. Table 2 shows the contractor's general specifications. This prototype ABI is the only such unit scaled for small commercial/industrial operations. It consists largely of off-shelf or hand-made auxiliaries assembled to demonstrate the innovative furnace concept. It was the objective of this study to evaluate the system as assembled for possible immediate use at Army installations to study the furnace concept for possible future use, should the tested systems prove to be unreliable because of the off-shelf and hand-made auxiliaries.

Process Flow

Major unit operations evaluated at the plant included delivery and handling of solid waste, removal of bypass wastes, feeding, combustion, ash removal, heat exchange (steam production), and off-gas cleaning (air pollution control). Solid waste delivered by collection vehicles is dumped on a poured concrete slab and moved to the incinerator feed hopper by front-end loader. There is minimal separation of bypass materials at this point. Waste is moved from the feed hopper by inclined drag conveyor to the incinerator loading point at the top front of the unit. All controls for operating the ABI are at this point; the operator visually identifies and removes bypass wastes as they approach the incinerator loading inlet. Waste falls approximately 7 ft (2.1 m) to the bottom front end of the unit, where it is captured by the first auger flight and conveyed to the furnace ignition zone.

One gas-fired ignition burner is located on each side of the furnace in the ignition zone. When nominal fur-

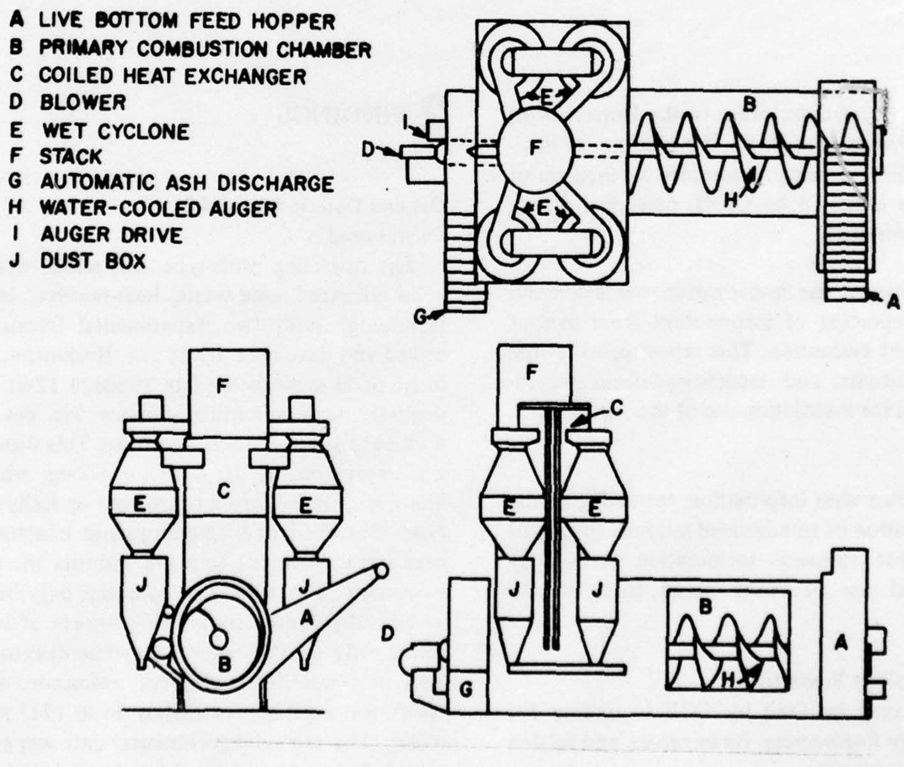

Figure 2. General schmatic of ABI.

Table 2
General Specifications of Prototype ABI Evaluated
(Metric Conversion Factors: 1 ton = .907 metric ton; 1 ft = .3 m;
1 in. = 25.4 mm; 1 CFM = .02832 m^3; 1 Btu = 1048.5 J;
1 gal = 3.78 ℓ; 1 lb = .45 kg.)

Capacity	5 tons per hour of household-type waste from packer-type trucks. (100 tons per day)
Dimensions	35 ft – length 18 ft – width 22 ft – height (ground level to top of stack)
Combustion Chamber	24 ft – length 8 ft – diameter
Refractory	7½ in. thick A. P. Green – 2700°F
Auger	32 ft – length 66 in. – diameter
Combustion Air Source	(1) 20 hp–2250 rpm blower – capacity 6500 CFM
Pollution Control	(4) cyclamatic collectors (4) 20 hp–2250 rpm blowers – capacity 6500 CFM
Auxiliary Burner	(2) Gas Burners – 80,000 Btu each
Ash Removal	Rex chain belt
Feeder System	Live-bottom conveyors – ground-level feeding
Controls	Electric-hydraulic panel with overall view of operations for operator
Drives	Variable hydraulic drives on all augers, feeders, and ash removers – belt drives on fans
Power	3-phase – 220-V with 400-amp panel
Hydraulic System	5-hp pump – 40-gal reservoir
Water Requirements	25 gal per minute
Water Pump	10 hp electric
Foundation	6 ft × 24 ft × 8 in. reinforced concrete slab with apron as desired
Area Required	165 ft × 130 ft machine and accessories
Erection Time	160 man-hours
Break-in Time Required	1 week
Operator Training Time	2 weeks
Shipping Weight	37 tons
Steam Generating Capacity	approximately 25,000 lb per hour

nace operating temperature has been attained, waste ignition is largely self-sustaining, and it is not necessary to continuously fire either burner. Waste is conveyed through the furnace by the auger, which is set eccentrically so that the top clearance is approximately 2.5 ft (0.8 m) and bottom clearance approximately 2.5 in. (64 mm). Each flight has 0.25-in. (6.4-mm) holes around its perimeter through which combustion air is supplied by a forced-draft fan located at the rear of the unit.

Ash is conveyed by the water-cooled auger to a quench pit, from which it is removed by inclined drag conveyor to a waiting truck or stationary container. A modular coiled heat exchanger is located in the stack base above the rear of the furnace before the ash quench. Off-gases pass through the heat exchanger to any of four modular wet cyclonic separators installed symmetrically around the stack. Water spray for each separator is located at its respective inlet duct. Each separator has its own induced-draft fan, which draws cleaned gases through the system for venting to the atmosphere though a stack. Sludge from the separators is temporarily contained in a "dust box" below each unit, which is emptied as required.

General Operational Aspects

The prototype ABI was assembled on a low budget from hand-made, off-shelf, and salvaged parts. The evaluation indicated clearly that the existing system is not ready for production. As indicated by the test chronology (Appendix D), downtimes during the evaluation were due to operator fatigue and failure of mechanical auxiliaries and not to malfunction of the major components of the system (the furnace, auger, and heat exchanger).

The concept itself has inherent advantages and disadvantages. The foremost advantage of the ABI is its observed capability to process at least three times more waste than currently available modular incinerators. However, based on CERL estimates, it appears that the ABI processed 75 tons (68.3 mt) of mixed residential/light industrial solid waste during the test period. At peak load, the ABI appeared to be processing 3.5 tons/hour (3.2 mt/hour) for a period of 7 hours.

A second inherent advantage of the ABI is its site requirements. The unit is semi-portable, can rest either on a poured concrete or crushed gravel foundation, and does not have to be level. According to the principal contractor's specifications shown in Table 2, 5 to 7 man-weeks are required for erection and startup of the 37-ton (34-mt) unit. If this is true, the implementation costs of the ABI will be substantially lower than for other modular incinerators. The general profile of the ABI may permit its installation in existing rather than new installation enclosures (e.g., vacated warehouses), thus reducing construction costs.

Nonetheless, the operating prototype ABI had numerous technical disadvantages observed during the evaluation. As indicated during the preceding discussion on unit operations, nearly every mechanical auxiliary requires re-engineering before the ABI can be considered practicable. The unit requires thorough instrumentation and improved controllability based on actual physicochemical conditions rather than on the intuition of an experienced operator. A production model ABI made of improved materials, properly instrumented, with better engineering, is expected to cost more than the $600,000 price of the prototype. Combustible materials longer than 36 in. (914 mm) were removed by the principal contractor from the ABI feedstock. Since Army installations generate an appreciable quantity of wood scrap, sheet cardboard, large packaging materials, pallets, and skids, these materials would have to be reduced in size to be accepted by the furnace.

Of central interest during the evaluation was the furnace, which had accumulated approximately 2000 intermittent hours of operation when the test began. Post-operational inspection indicated less-than-expected wear on the refractory and auger material. Observations during the test indicated that, at peak load, from 3 to 4 tons (2.7 to 3.6 mt) of waste were being processed at furnace temperatures ranging upward to approximately 2000°F (1093°C).

Evaluation of Unit Operations

This section is a consolidation of notes taken by CERL and other military personnel who witnessed operation of the prototype ABI. Commentary on each major unit operation is furnished.

Initial Delivery and Handling

Solid waste was delivered to the site in as-collected condition by private haulers serving the residential/light-industrial area of near-southwest Jacksonville. Waste delivered during the test period did not conform strictly to any IIA classification type, and was mostly atypical of waste found on most Army installations, where greater fractions of paper, cardboard, wood, and plastics by weight are generated.

Delivered waste was dumped directly onto an outdoor poured-concrete slab adjacent to the ABI, which was also unsheltered. Two diesel-powered front-end loaders were available, each at a different time during the test. Each had approximately 1.50 cu yd (1.15 m^3) of bucket capacity, and one unit was equipped with a hydraulic backhoe.

The front-end loader was used to move waste from its delivery point to the ABI feed hopper. The waste was moved by pushing rather than lifting. There was no separation of bypass wastes between delivery and entry of the material into the feed hopper. The front-end loader was manned approximately 70 percent of the time that the ABI was in operation; the balance of operator time was spent directing waste deliveries, assisting in ash removal operations, and performing minor housekeeping and maintenance duties.

Fuel consumption of the front-end loaders averaged approximately 2 gal/ton (0.008 m^3/mt), including idle time.

There appeared to be no potential major problems in using the tipping-floor/front-end loader system in preference to alternative initial handling systems such

as the pit-and-crane operation. Successful use of the loader system in plants processing 650 tons/day (592 mt/day) and more of solid waste is well documented,[5,6] although it is prudent to design an enclosed dumping area with sufficient space to store delivered waste that accumulates when process equipment is down.

Feeding and Loading

As-collected waste was moved by front-end loader to a steel feed hopper (Figure 3) equipped with a variable-speed, hydraulically driven drag-link chain conveyor that moved the material along the length of the hopper and up a 40-degree incline approximately 12 ft (10.8 m) to the feeding end of the furnace. The feed hopper measured 4 ft (1.22 m) deep, 8.5 ft (2.6 m) wide, and its floor was approximately 1 ft (0.3 m) below grade. The hopper was walled on three sides with bolted mild steel sections 3 ft (0.9 m) high and opened toward the waste delivery area. The steel walls around the inclined conveyor were of similar construction and integrated into the hopper walls.

Loading was by gravity. Waste moved by the conveyor fell into the ABI loading end and approximately 7 ft (2.1 m) to the furnace floor where it was captured by the first auger pitch and moved to the ignition area. Bypass wastes were usually identified and manually removed by the operator at the loading point. Numerous times during the test it was necessary to halt the feed conveyor and auger drives to remove larger bypass materials from the feedstock (Figure 4). Location of the operator station near the feed point facilitates this acitivity.

It appeared that proper operation of the ABI feed system could be achieved by using a portion of operator time to separate bypass wastes. However, requiring manual removal of bypass wastes is questionable for several reasons:

1. The operator must have physical contact with the feed material, much of which is either contaminated with infectious organisms or is directly injurious, such as spikes, broken glass, nails, etc.

[5] *Report on Status of Technology in the Recovery of Resources from Solid Wastes* (Sanitation Districts of Los Angeles County, CA, 1976).

[6] *Recovery I, New Orleans, LA* (National Center for Resource Recovery, 1976).

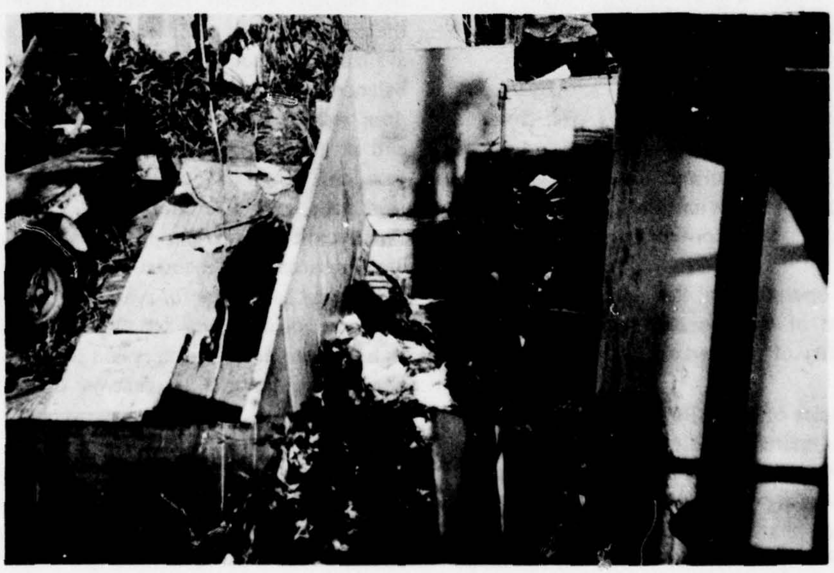

Figure 3. Feed hopper and conveyor to ABI loading level.

Figure 4. Bypass wastes removed from ABI feedstock during test.

2. The operator must physically remove large and/ or heavy items which may overtax his strength.

3. Performing bypass waste removal fatigues the operator, whose principal duty is the properly controlled mechanical performance of the equipment.

4. It is inherently unsafe to pick material from a moving conveyor. As shown in Figure 5, the front-drive sprocket is exposed at the furnace feed point, which can cause both waste materials and the operator's clothing to be caught, and is thus a potential cause of injury.

5. The proper operation of the ABI is contingent upon the judgment of the operator regarding the nature and acceptability of the feedstock.

Several deficiencies of the ABI loading system were noticed during the evaluation. First, there was considerable blowback of dust and light materials when waste dropped into the loading end of the ABI. The principal contractor indicated that he had prepared a plexiglass shield to protect the operator, but it was not installed for the test. Second, when highly combustible materials (e.g., pine sweepings) were fed, ignition was very rapid, and flame belched upward from the loading end above the operator station. This occurred several times during the test, and only a 0.25-in. (6.4-mm) garden hose was available for quench. Third, system draft was delicately balanced. Numerous times when the rear inspection door was opened, smoke billowed out the front feed end at the operator station (Figure 6). In the worst case, this could have caused a reversal of the combustion path, with fire concentrated in the feeding end. Finally, the receiving hopper was installed below-grade with no access for maintenance or cleanout, making it a potential harborage for pests and vectors. In addition, a jam-up could cause lengthy downtime before mechanical problems are accessed and corrected. In cold climates, water could freeze in the receiving hopper and render it inoperable.

Operation of the loading process required constant observation by the operator. During the test, his duties were equally divided between bypass waste removal, operation of ABI controls, and miscellaneous work

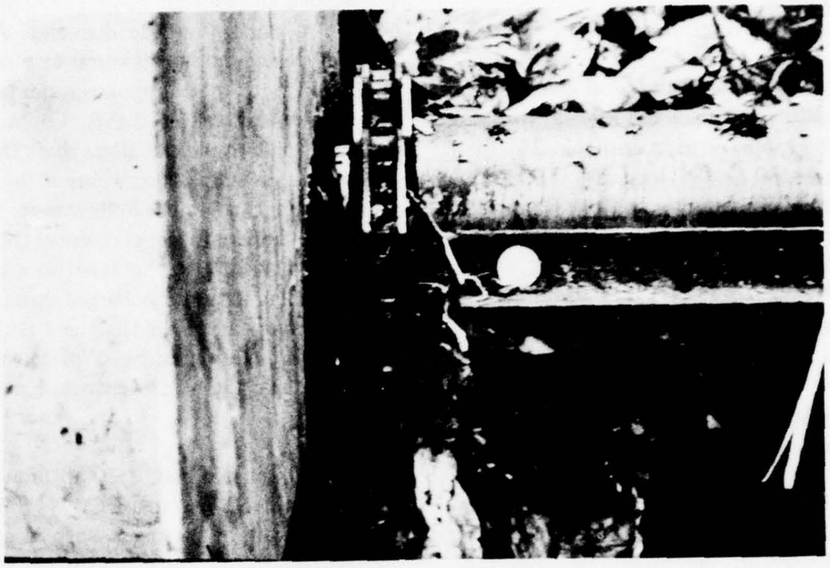

Figure 5. Exposed front-drive spocket of feed conveyor at discharge point.

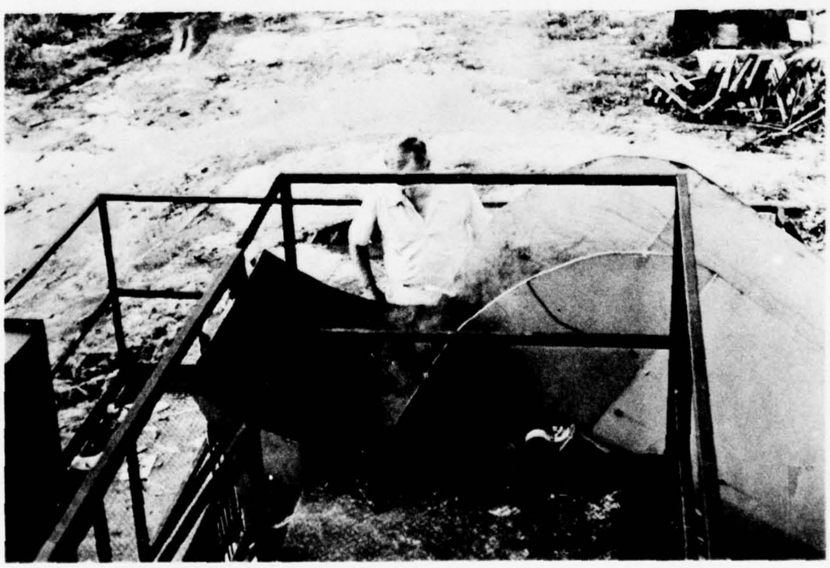

Figure 6. Blowback of smoke to loading end near operator station caused by draft loss.

which included minor repairs and maintenance. The feed conveyor was driven by a 5-hp motor and was operational approximately 75 percent of the time that the ABI was functioning.

Furnace

The ABI furnace is a fixed cylindrical combustion chamber, horizontally positioned and leveled, with an approximately 8-ft (2.4-m) outside diameter. The furnace is made of three 8-ft (2.4-m)-long cast, refractory-faced, mild-steel-clad, bolt-together sections (Figures 7 and 8). Section 1 is faced with A. P. Greene 2000°F (1093°C) refractory material, while Sections 2 and 3 are faced with A. P. Greene 2500°F (1371°C) refractory material. Refractory thickness throughout the furnace is uniformly 7.5 in. (190.5 mm). There is no insulation.

The 10-flight constant-pitch auger extends the length of the combustion chamber and rotates on bronze bearings mounted in the end plates of the chamber. The end plates are bolted to the furnace housing to permit removal of the entire auger unit. The auger is eccentrically positioned in the furnace so that top clearance is approximately 2.5 ft (0.8 m) and bottom clearance is approximately 2.5 in. (64 mm). The auger is a 14-in. (356-mm)-diameter black iron pipe welded to a 0.25-in. (6.4-mm) iron sheeting that has been cut and shaped to form an 11-in. (279-mm) auger with a 66-in. (1676-mm) outside diameter. A 3-hp electric motor-driven pump injects water at a reported 200 psi (1379 kPa) into the continuous water jacket welded to the base of the auger flights. Cooling water is fed through a pipe inside the auger shaft from the loading end to the discharge end, where it then counterflows over the supply pipe. The hollow auger blade is divided into two chambers; the inner chamber (smaller diameter) is open to the shaft so that it is also water-cooled. The heated cooling water is discharged through a rotary seal at the loading end of the shaft and is then boosted in pressure through a positive displacement boiler feed-water pump to the heat exchanger located at the base of the stack.

At the discharge end, a 20-hp blower injects combustion air at 6000 actual CFM (1700 m^3/min) into the hollow core of the auger shaft. At a distance of approximately 4 ft (1.2 m), the shaft is sealed, and air is forced into the continuous channel (larger diameter) in

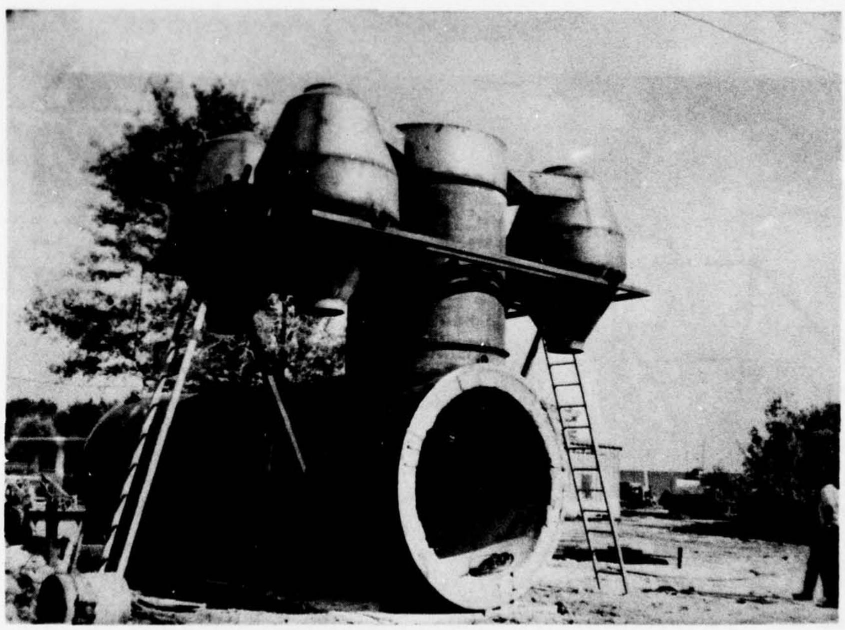

Figure 7. General profile of ABI showing three-section furnace assembly.

Figure 8. Bolted assembly of furnace sections 1 and 2.

the hollow outer edges of the auger flight. Combustion air enters the furnace volume through .25-in. (6.4-mm) holes in the outer faces of the flights (Figure 9). Pressure drop in the air system is 10 in. (254 mm) water gauge. Secondary combustion air is drawn into the furnace as required by one or more of the cyclone-separator induced-draft fans as determined by the operator to prevent smoke from backing out of the feeding end.

The auger is rotated by a 5-hp, variable-speed, hydraulically operated drive unit which also provides drive power for the feed conveyor. The drive has reverse capability to permit freeing large, hard objects that might jam between the auger and combustion chamber wall. The principal contractor indicated that the bearing housing on the charging end of the auger shaft was constructed with 18-in. (457-mm) vertical free play to permit auger flights to ride over large objects. This characteristic was not observed during the test. There is no method to free an auger jam-up that cannot be corrected by backing or joggling the auger drive. There is no side entrance to the furnace, and there are no furnace inspection ports other tha a man-hatch at the discharge end.

Ignition is by two 5 MBtu/hour (5275 J/hour) gas-fired burners located on either side of the combustion chamber immediately before the loading volume. During the evaluation, the ABI was cold-started several times with the ignition burners continuously firing. Following cold-start (20 to 30 min), the burners were operated only intermittently. The combustion of wet waste was observed to be fuel-consuming. Two burners were needed to ignite the material while the auger was stationary in order to provide greater residence time for drying and ignition, thus reducing the furnace throughput capacity.

Combustion gases exit through a 5-ft (1.5-m)-diameter stack at the discharge end of the furnace, which contains a coil-type heat-exchanger. At the discharge end of the furnace, ash is deposited into a concrete water quench tank which is integraily constructed as part of the combustion chamber unit.

During post-operational inspection, refractory deterioration was observed in the first section of the unit (Figure 10). Pitting and fine cracking were predominant, and in some places 3-lb (1.4-kg) jagged blocks of re-

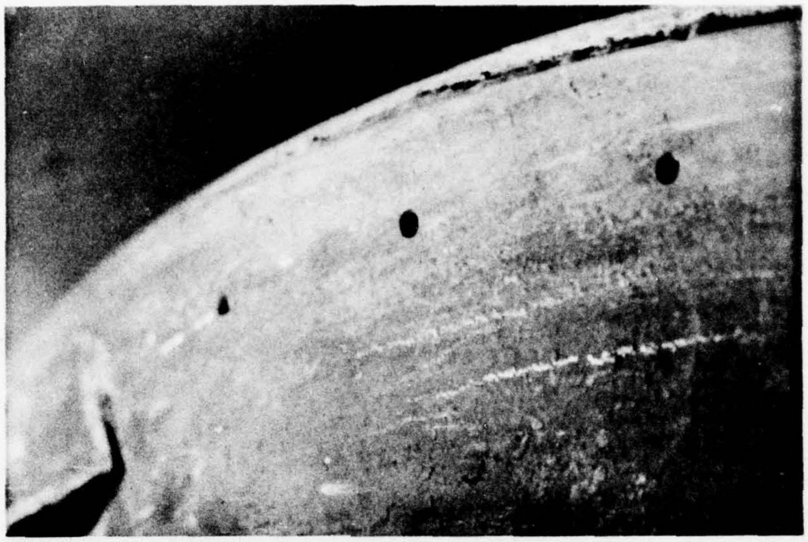

Figure 9. Holes in perimeter of auger flight to supply combustion air.

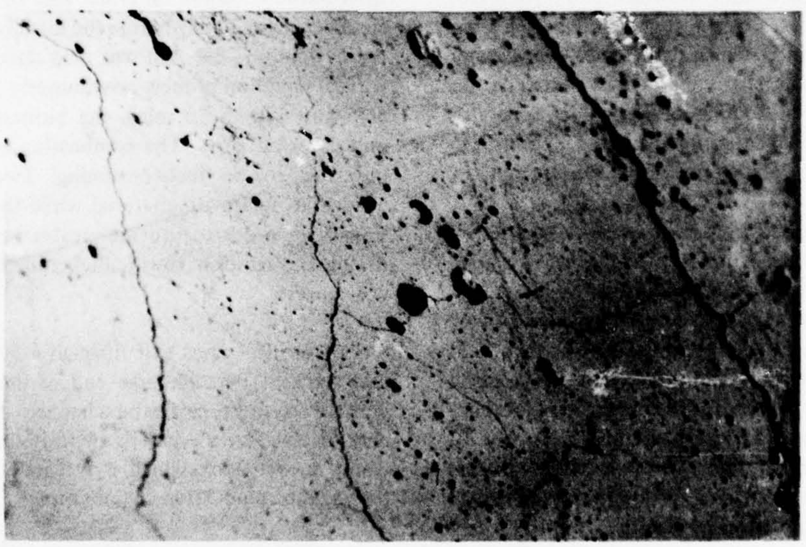

Figure 10. Refractory wear in furnace section 1.

fractory had fallen from the furnace roof. This was attributed to several factors. First, this section of the combustion chamber is faced with a lesser quality of coarse-aggregate refractory than the two downstream sections, which displayed less deterioration (Figure 11). Second, the forward furnace section is the ignition zone and is exposed to flame impingement and thermal stress. In the case of thermal stress, temperatures fluctuate as burners are activated and as combustible waste is fed; the entry point to the furnace has no air seal, so cold air enters the furnace by draft through the 3-ft (0.9-m) clearance between the auger shaft and a hanging steel guillotine separating the loading and ignition volumes. Abrasive effects of falling waste on both the auger material and furnace refractory at the loading end were minimal. Post-operational inspection of the furnace refractory indicated that the floor had endured the scouring effects of abrasive wastes moved by the auger; while the floor was thoroughly charred, few striations were apparent. No bottom ash was found in the furnace, suggesting that the auger has a cleaning affect.

Observations during the evaluation period indicated that the auger does not mechanically mix the burning waste to an appreciable extent. Instead, the material is moved through the furnace in small plugs, each burning at its own rate. The auger flights are therefore separators which provide curtains of combustion air to small batches of burning material contained between them. Nevertheless, the principal combustion zone is generally limited to the front 60 percent of the furnace, probably because most waste attains self-sustaining combustion within the maximum time required to travel this length. Average auger speed during the test was 0.25 rpm. Approximately 30 min were required for the flame front to reach the discharge end. Temperatures in the principal combustion zone averaged between 1000°F and 1200°F (538°C to 649°C), during the entire test period. The operation was conducted for approximately 6 hours at temperatures averaging approximately 2000°F (1093°C) in the principal combustion zone. However, the flame during this period extended to the discharge end of the furnace. Burning particles floated in the ash quench, and flame color at the end of the auger was dark red, indicating a temperature of 900°F (482°C). Complete waste combustion under these conditions was not achieved.

Figure 11. Refractory wear in furnace section 2.

A major problem involving the auger performance caused substantial downtime during the evaluation. A vapor or air lock formed at the midway point in the water jacket, preventing circulation of essential cooling water. There are two possible reasons for this, although the exact cause is not known. First, water to the auger (and ultimately to steam in the heat exchanger) was virgin, obtained from a municipal hydrant located 100 yards (914 m) from the site. Since the water was not deaerated, air could have escaped and collected in a pocket. However, a more probable cause was that water evaporated to steam in the water jacket in the principal combustion zone of the furnace. Separation and steam pocket formation could have occurred easily while the auger was at rest or slowly moving. The solution to the problem was to reverse the auger drive and purge the trap through the loading end of the unit. However, when this was done, the six 0.25-in. (6.4-mm) chrome-alloy bolts mounting the 250-lb (113-kg) main front auger drive sprocket sheared. Feeding of the waste ceased, and all four cyclones were activated to purge heat from the furnace to prevent overheating of and resultant damage to the auger material. Repair of the front-drive assembly (Figure 12) required 2 hours. Upon restart, however, an auxiliary front-drive sprocket failed, releasing the drive chain. During earlier remount of the main-drive sprocket, the auxiliary sprocket was accidentally struck to an offset position. Eleven hours were required to realign and repair the front-drive assembly.

Post-operational inspection of the auger indicated that some corrosion (Figure 13) and abrasion had occurred. There was also warpage in nearly all areas of the water jacket, thus increasing the possibility that the welds fastening it to the auger would split. A unified construction would avoid the weld-splitting problem, but it is doubtful that abrasive effects could be reduced. On the other hand, use of a more resistant alloy could reduce the rate of high-temperature corrosion of the auger material.

Finally, the incidence of wire wrapping around the auger shaft at the discharge end was high (Figure 14), although many wire products passed through the furnace without difficulty. The trapped wire was removed with a welding tool.

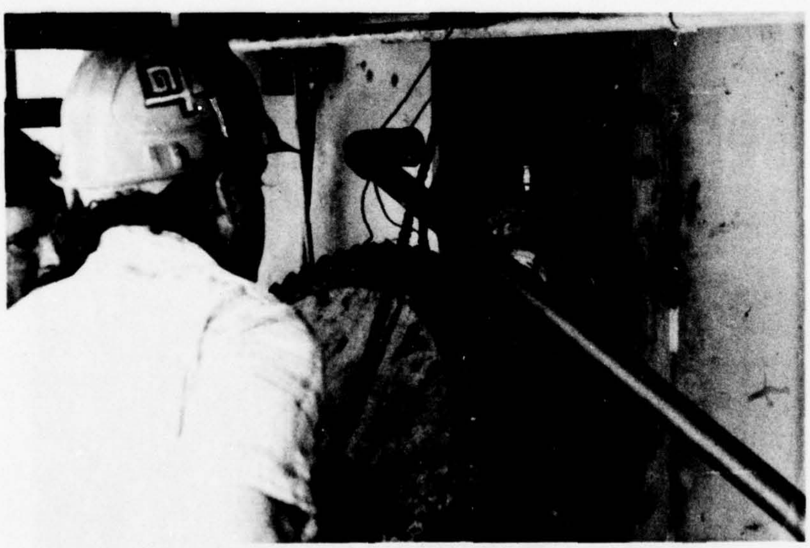

Figure 12. Assembly of main auger drive.

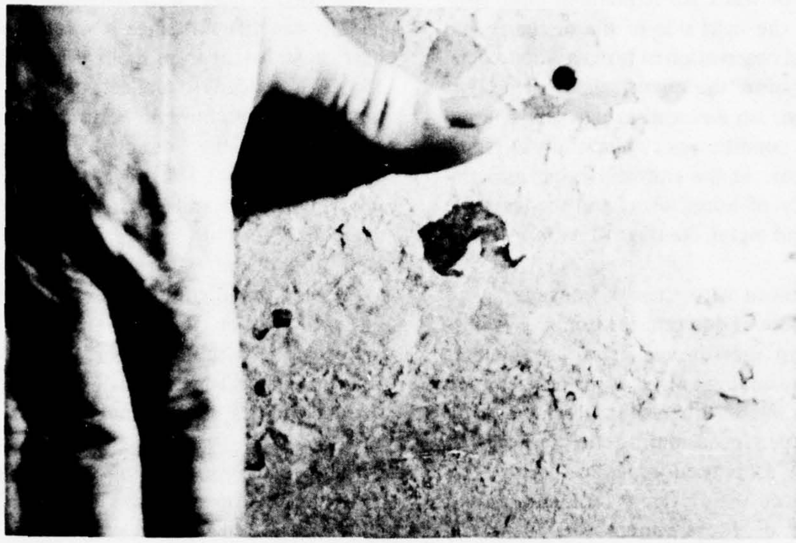

Figure 13. Corrosion of auger material.

Figure 14. Wire wrapped around rear auger shaft.

Ash Removal

As the burned material was moved forward by the auger, it dropped approximately 6 in. (152 mm) into a water-filled ash pit from which it was removed by a hydraulically driven, inclined, drag-link chain-conveyor to a waiting container or truck for ultimate disposal (Figure 15). A door on the right side of the discharge end of the unit permitted observation of furnace phenomena and ash condition before the quench. During the first 30 min of operation, ash emerged in partially charred states (Figure 16), a condition not unusual during start-up of any incinerator. At the end of 1 hour, ash consisted predominantly of ashes, char, and recognizable fragments of glass and metal. No slags were observed.

Problems experienced with the ash conveyor were the largest single source of downtime during the evaluation. It was apparent that the ash removal system is deficient and that the equipment used was not designed for this application. With thoughtful design, ash removal problems experienced during the test period should be overcome. Unburned materials, particularly textiles, severely fouled the drag conveyor, and on two occasions untracked it. There were several instances when wire and cable caused jamming and had to be cut away with a welding tool (Figure 17). On one occasion, a small bed-spring became trapped in the 18-in. (457-mm) crown at the quench exit; the jam-up was not immediately accessible from the rear door because of the high furnace heat. Even after cooldown, clearing the jam-up was difficult since it was on the side of the furnace most distant from the rear inspection door (Figure 18). Ash tended to collect on top of the conveyor housing at the conveyor return; flies swarming in this area indicated the presence of organics, a sign of incomplete burnout (Figure 19). Observations of the ash pile (Figures 20 and 21) indicated a large variation in degree of burnout, due principally to the numerous cold-starts during the test period. However, thick catalogues and wood studs were rarely burned completely. With the former, this indicated absence of in-furnace mixing, and with the latter, it suggested insufficient residence time for combustion—an operational rather than mechanical shortcoming.

A major concern during the evaluation was the inability of the operator to see or monitor the essential parts of the ash removal system from the control sta-

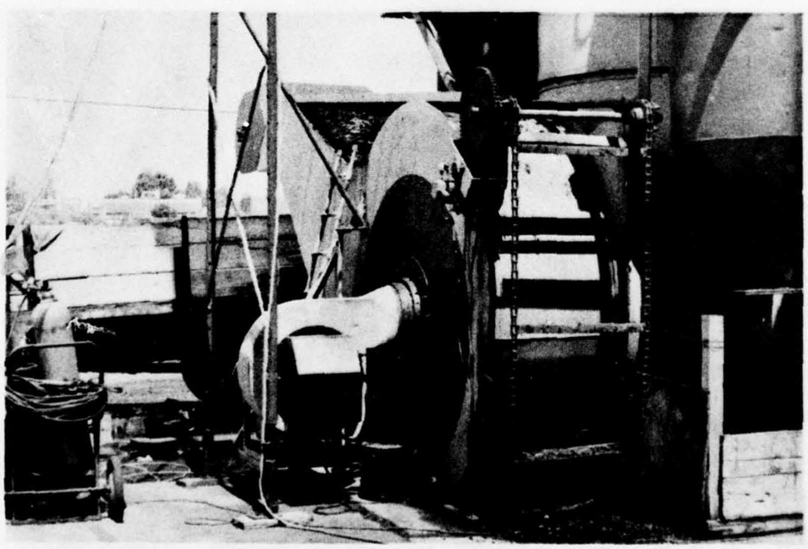

Figure 15. Ash removal system at ABI discharge end.

Figure 16. Charred ash after startup.

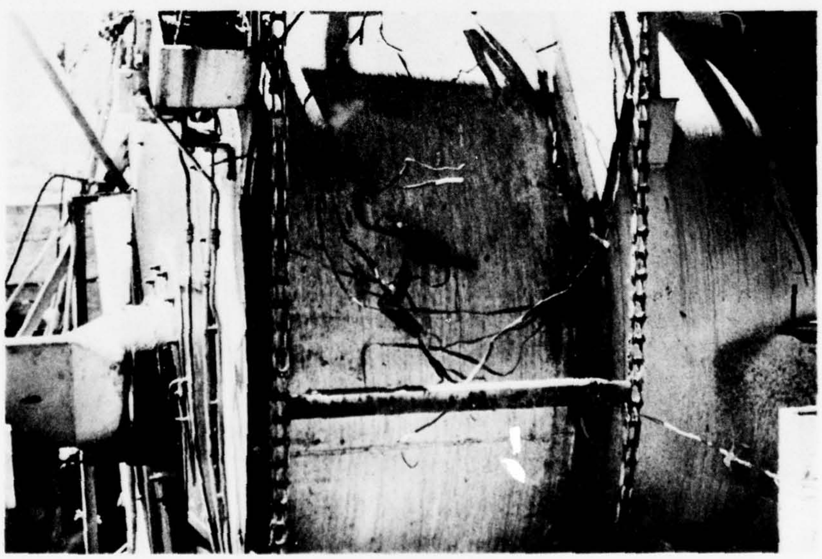

Figure 17. Jamming of ash conveyor with wire.

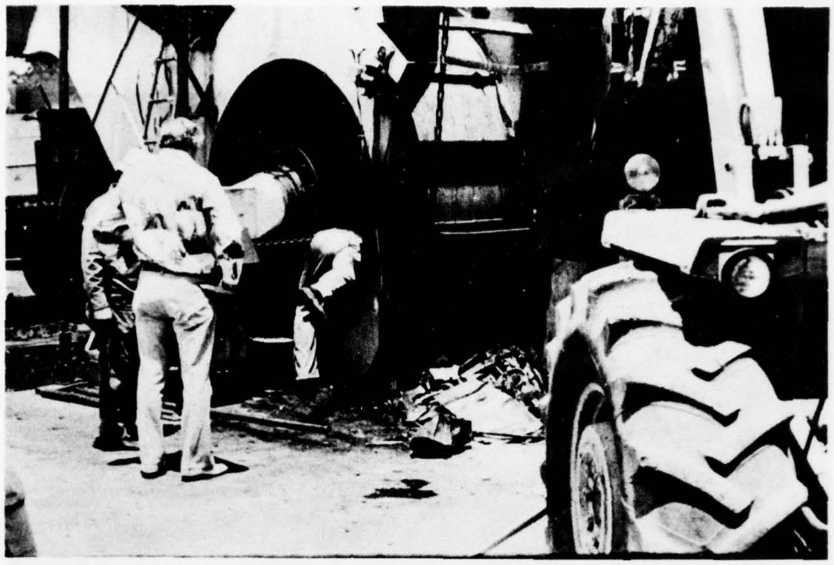

Figure 18. Use of rear inspection door to clear ash jam-up.

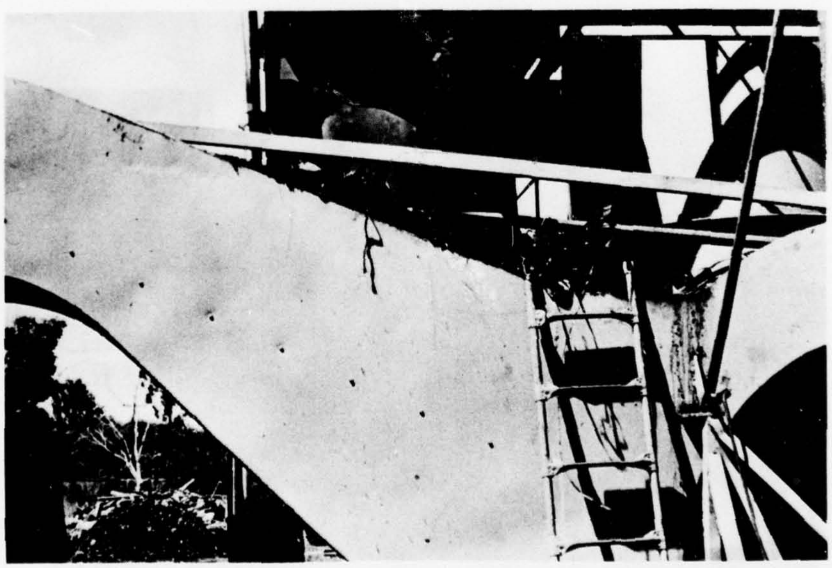

Figure 19. Ash collected on top of conveyor housing at conveyor return.

Figure 20. Ash pile.

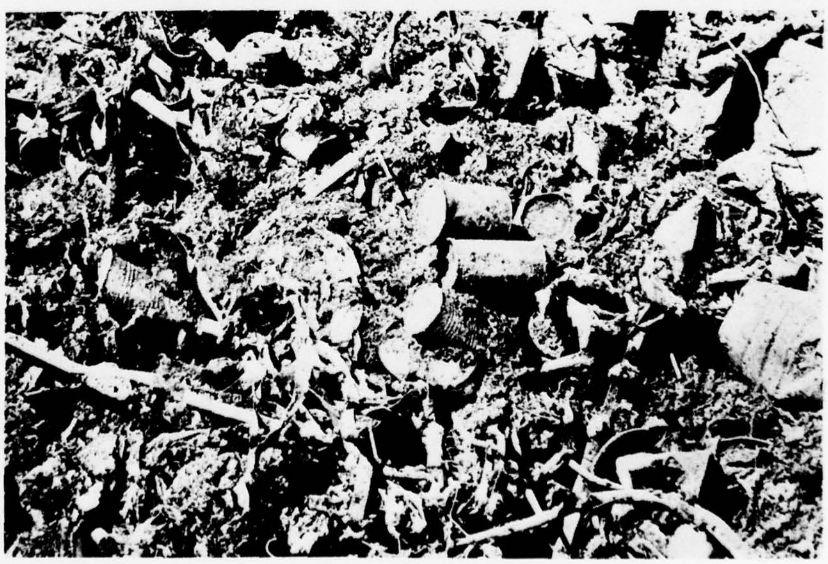

Figure 21. Closeup of accumulated ash.

tion; only the discharge point of the drag conveyor was visible, and there was no instrumentation. As a result, a jam-up in the ash removal system could not be identified before it had already developed into a substantial problem. Moreover, the quench system had no drain; on one occasion, the water feed was left on when the operator went off duty, and the furnace was filled with 1 ft (0.3 m) of backed-up water when he returned several hours later.

Perhaps a more significant design shortcoming was the location of the hydraulic lines to the ash conveyor drive relative to the position of the rear inspection door. When the door was opened wide, its bottom edge would abut against the hydraulic lines, damaging them and creating a potentially hazardous situation (Figure 22).

Heat Exchange (Steam Production)

The heat exchanger is located above the discharge end of the furnace approximately 3 ft (0.9 m) before the ash quench. The heat exchanger is a continuous coiled element with 11 tiers and has the general configuration shown in Figures 23 and 24. The stack is blanked off above the coil, forcing gases to travel through the coil to one or more of the four cyclonic separators located around the stack. The unit evaluated was not equipped with a steam-water separator. Mixed heat-exchanger product was piped approximately 120 ft (37 m), where it was released on the grounds of the test site. The heat exchanger was fed with water preheated during its travel through the auger. No provision was made for controlling feedwater pH and hardness or for deaeration. It was not possible to determine the amount of steam being produced, but based on the amount of water consumed and the feedwater pressure, it was estimated to be between 4,000 and 10,000 lb/hour (1136 to 2841 kW) at pressures fluctuating between 100 and 250 psig (689.5 to 1723.8 kPa).

The three major areas of concern about the heat exchanger were temperature control, inlet gas velocity, and flame inpingement. The ABI being evaluated had no means to control coil temperatures. It was observed that the coil was subject to wide temperature fluctuation as burning waste was moved through the furnace. Since

Figure 22. Impingement of rear inspection door on hydraulic lines.

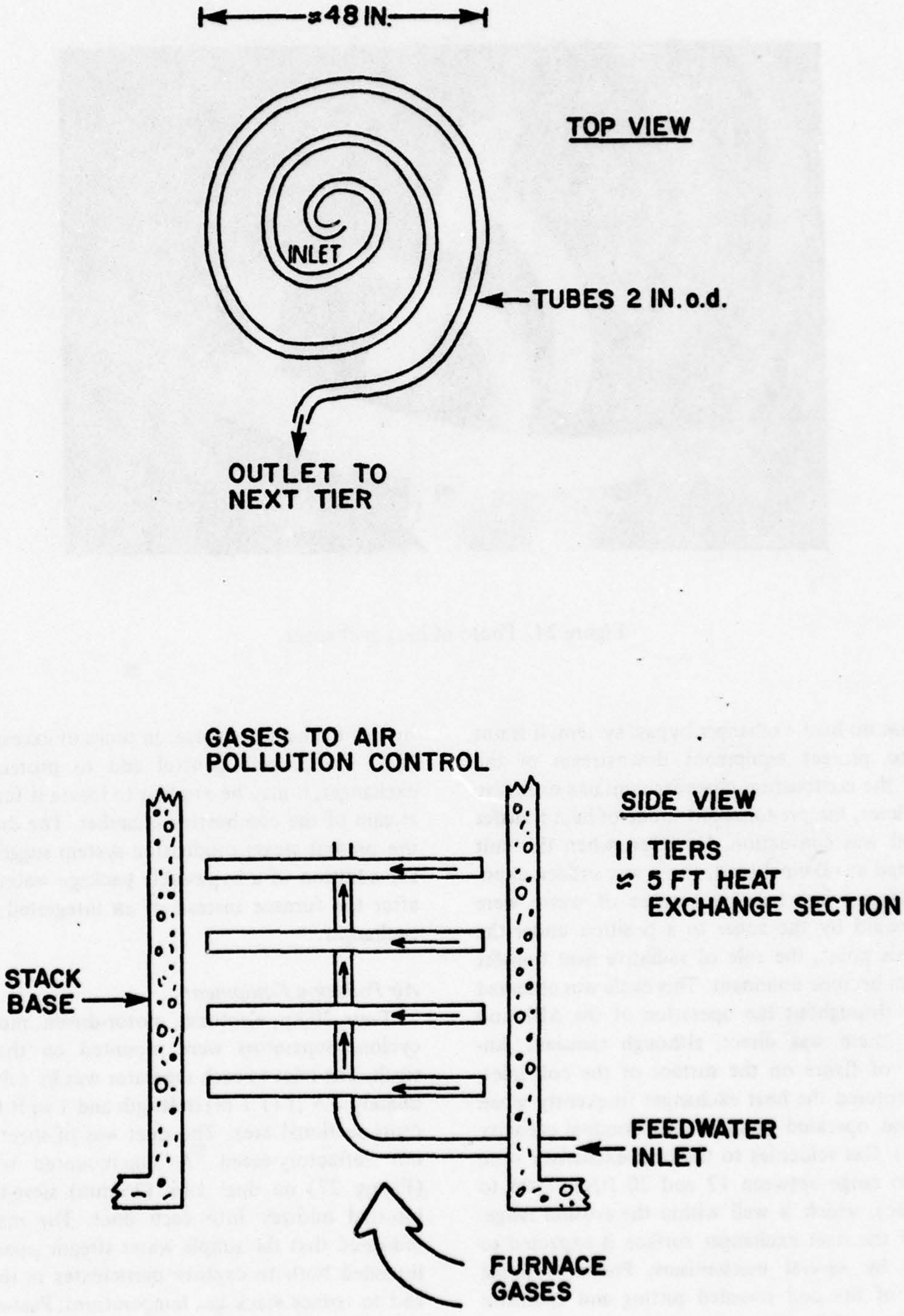

Figure 23. General schematic of heat exchanger.

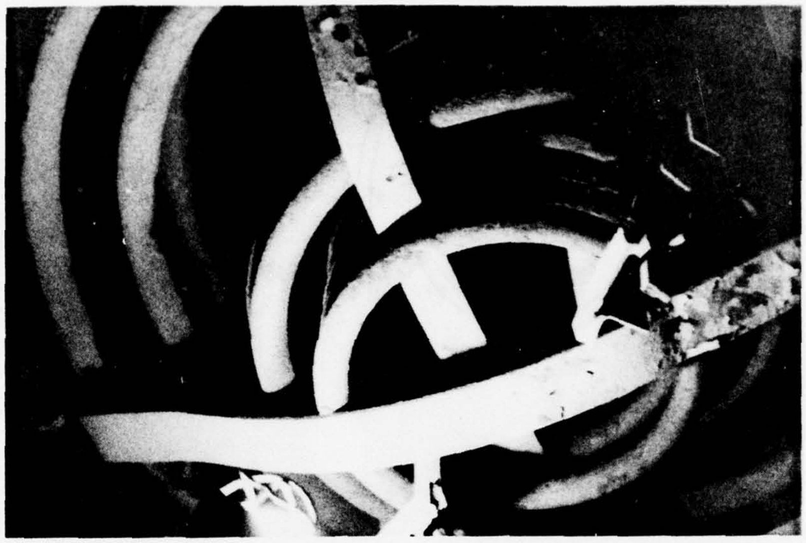

Figure 24. Photo of heat exchanger.

the ABI has no heat exchanger bypass system, it is not possible to protect equipment downstream of the furnace if the combustion chamber contains excessive heat. At times, the predominant mode of heat transfer to the coil was convection. However, when the unit was operated at nominal load, there was sudden exposure to flame when burning batches of waste were moved forward by the auger to a position under the coil. At this point, the role of radiative heat transfer would again become dominant. This cycle was observed constantly throughout the operation of the ABI, and frequently there was direct, although transient, impingement of flame on the surface of the coil inlet. Sparklers entered the heat exchanger frequently when the ABI was operated at and below nominal capacity (Figure 25). Gas velocities to the heat exchanger were observed to range between 12 and 20 ft/sec (305 to 508 mm/sec), which is well within the erosion range. Wastage of the heat exchanger surface is expected to be caused by several mechanisms. Post-operational inspection of the coil revealed pitting and extensive spalling (Figure 26), giving reason to expect that the heat exchanger will not endure even the most modest economic life. The system had no means by which to bypass the heat exchanger in times of excessive furnace heat. To provide control and to protect the heat exchanger, it may be prudent to locate it further downstream of the combustion chamber. The drawbacks of the present steam production system suggest the need for addition of a bypassable package watertube boiler after the furnace instead of an integrated coiled heat exchanger.

Air Pollution Equipment

Four 20-hp, electrical, motor-driven, modular, wet-cyclone separators were mounted on the discharge stack. The inlet to each separator was by a duct approximately 3.5 ft (1.1 m) in length and 1 sq ft (0.1 m^2) in cross sectional area. The duct was of sheet metal and not refractory-faced. A side-mounted water spray (Figure 27) on dual 1-in. (25-mm) sieved pipes was inserted midway into each duct. The manufacturer indicated that the simple water stream separators were intended both to capture particulates in the off-gases and to reduce stack gas temperatures. Post-operational inspection of the No. 3 separator induced-draft fan revealed neither calcium deposits nor corrosion. This observation, along with data indicating that inlet gas

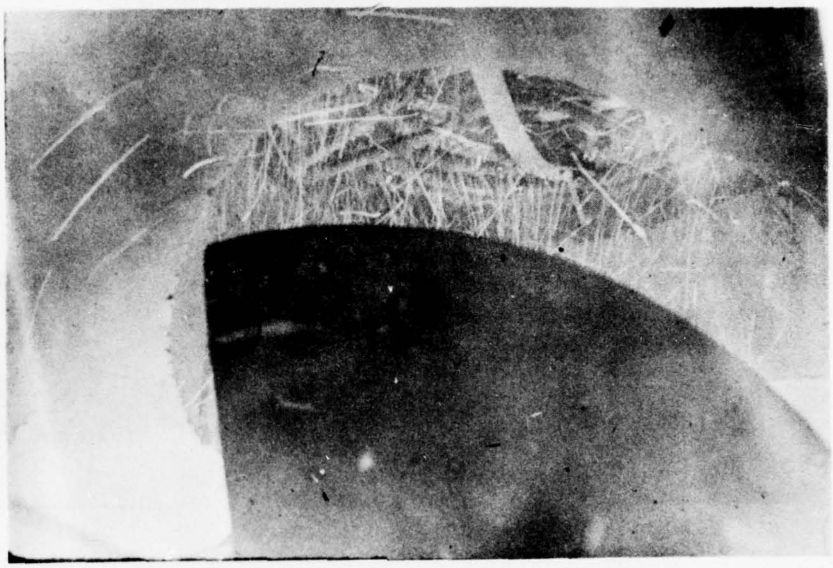

Figure 25. Sparklers entering heat exchanger.

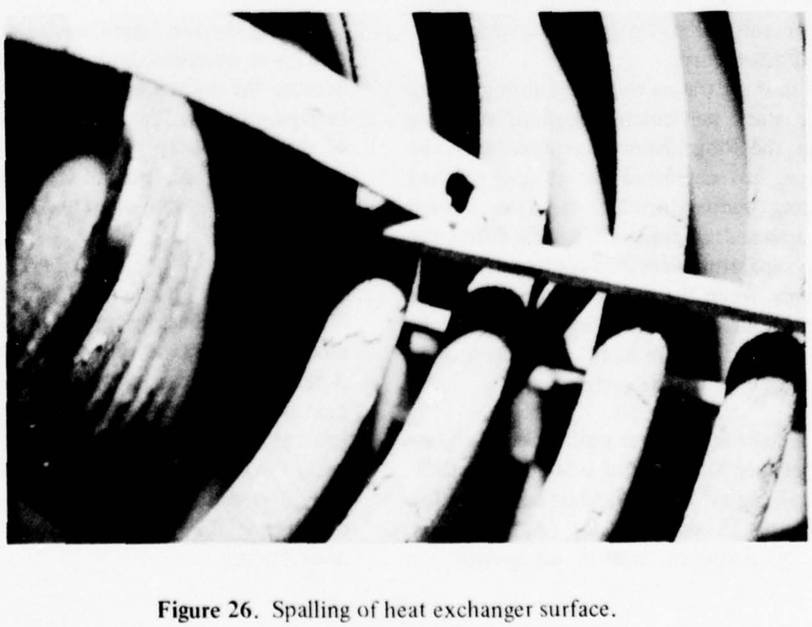

Figure 26. Spalling of heat exchanger surface.

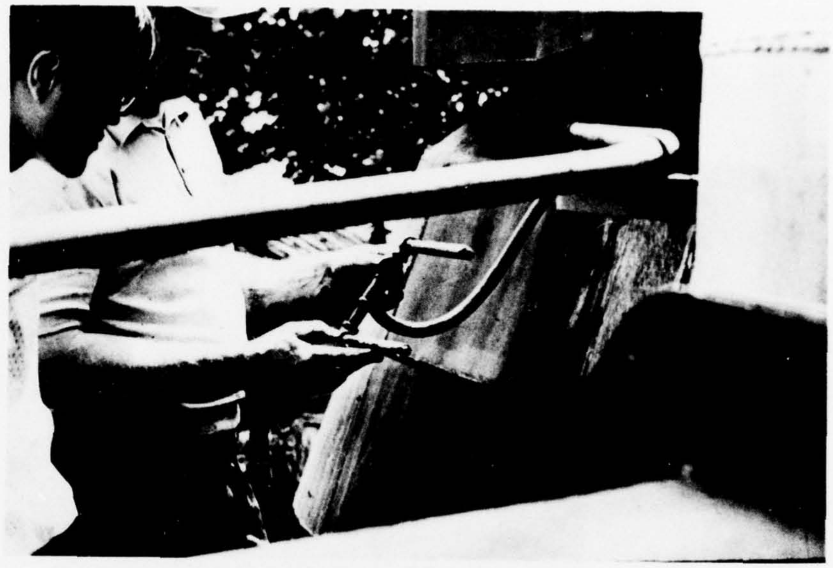

Figure 27. Water spray at cyclone inlet duct.

temperatures were approximately 700°F (371°C), suggests that the water stream was vaporized instantaneously as it entered the system and that droplet collection of particulates normally used in wet separators was therefore not present in the ABI. Continued observation of condensate and steam in the separator dust boxes supported this theory.

Three of the four separators were used during startup and during the stack particulate emissions sampling runs. At startup, the Ringelmann value appeared to be greater than one, but decreased as the unit reached nominal operating temperature The separator system was used as a furnace draft control regularly during the evaluation. Two separators were used continually during normal operations. When the rear inspection door was opened, causing smokeup at the loading end of the unit, the operator would activate an additional separator to restore proper draft through the system.

Despite the installation of four separators, stack test data indicate between 0.2685 and 0.5030 grains/SCF (0.4940 to 0.9255 mg/m^3) of particulate concentration in the off-gases at 12 percent CO_2 (Appendix A). Several types of pollution control equipment are commercially available which could be used to reduce emissions to within the U.S. Environmental Protection Agency compliance threshold of 0.12 grains/SCF (0.2208 mg/m^3).

During the test, rapid wastage of the inlet duct material was observed, and deterioration was accelerated because the ducts were not refractory-faced. The duct to separator No. 2 was severely oxidized just upstream of the water spray inlet. The duct to separator No. 3 warped during the test and separated from its connector mounting, rendering operation of the separator impossible.

Advantages of the air pollution control system included the backup provided by redundancy. This advantage could be enhanced with improved design. A second advantage was the capability to readily purge heat from the furnace when failure of auxiliary mechanical equipment required cooldown. It was possible to enter the combustion chamber for repair or inspection only after waiting 20 min following combustion. Cooldown time for the controlled-air incinerator requires several hours.

Stack and Draft

The prototype ABI was equipped with a 5-ft (1.5-m) diameter stub stack section extending 5 ft (1.5 m) above the heat exchanger section. For the field evaluation, a 4-ft (1.2-m)-diameter, 8-ft (1.4-m)-high section was added to facilitate stack gas particulate emission sampling. Both the stub section and the additional section were made of mild steel; the stub section was coated with a single layer of heat-resistant paint. Neither section was refractory-faced.

Combustion air was injected to the furnace through holes around the perimeter of the auger flights. Additional air sources were located at the furnace feed area and the rear inspection door. While a forced-draft fan supplied the auger air, there was no direct control over air entering from other sources. Air from the furnace was drawn to the stack by one or more of the cyclonic-separator, induced-draft fans, which were used by the operator as a draft control device to counteract adverse effects of air entering the system from uncontrollable sources.

Few problems involving stack and draft were observed during the evaluation. Post-operational inspection showed some warping and bubbling on the lower surface of the stack system's stub section, and there was substantial deterioration of the surface coating. Both these problems could be eliminated by lining the interior of the stack with refractory in accordance with traditional incinerator design practice.

Instrumentation and Controls

The ABI contained none of the permanent instrumentation customarily used in incinerator plants to indicate and/or record physical conditions. Instrumentation was limited to billing-type meters that continuously indicate, but do not record, electrical power and gas consumption.

The control system was not extensive. It consisted of three toggle-type hydraulic control valves to drive the feed conveyor, auger, and ash conveyor (Figure 28). These were installed at the operator station (Figure 29) near the loading end of the unit. A display panel

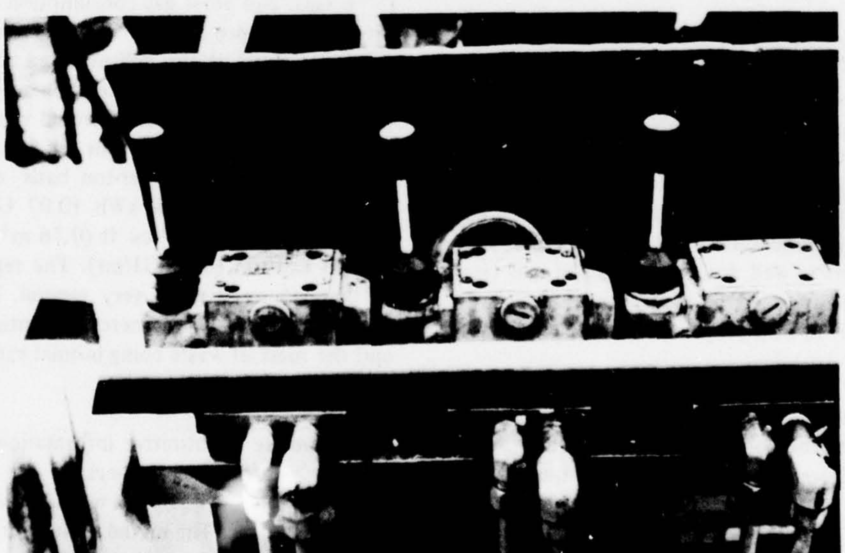

Figure 28. Hydraulic control valves at operator station to drive auger, feed conveyor, and ash conveyor.

Figure 29. Location of operator station.

to the right of the operator station contained indicator lights and on-off switches for the main electrical components of the system (Figure 30).

The field evaluation revealed that the instrumentation and control systems were highly deficient parts of the ABI; however, it was ackowledged that the ABI was an operating prototype assembled from parts which were hand-made, salvaged, and bought off-shelf, and that budget limitations did not allow for the added cost of instrumentation and controls. The nature and use of proper instrumentation and control systems for small incinerators is well documented[7], and it is clear that these elements could be incorporated easily into the ABI to conform with proper incinerator practice.

Energy Aspects

Accurate energy balance of the prototype ABI requires at least semi-continuous data on waste input, power and fuel consumption, and steam quality and quantity.

[7]S. A. Hathaway, *Design Features of Package Incinerator Systems*, Interim Report E-106/ADA040743 (CERL, May 1977).

Data recorded by CERL personnel during the test indicate that solid waste deliveries totaled 87 tons (79 mt), total electric consumption was 1600 kWh (5.76 GJ), and total gas consumption was 2000 cu ft (56.6 m^3). Approximately 8 tons (7.2 mt) of delivered waste remained at the delivery area at the end of the test. Bypass wastes accounted for an estimated additional 4 tons (3.6 mt) of delivered waste not entering the incinerator. Hence, 75 tons (68.3 mt) of waste were fed to the ABI. On a per-ton basis, electrical power consumption was 21.3 kWh (0.07 GJ/mt), and gas consumption was 26.7 cu ft (0.76 m^3), equivalent to 26,700 Btu/ton (0.03 GJ/mt). The representativeness of these figures is only very general. Throughout the test period, there were numerous downtimes and restarts, and the mass of waste being burned varied greatly with time.

No precise quantitative information on steam production was obtainable, because the prototype ABI evaluated was not equipped with a steam separator and metering system. The mixed steam-water product from the heat exchanger was vented through a pipe and released on the grounds of the test site. Observations indicated that the heat exchange efficiency is probably

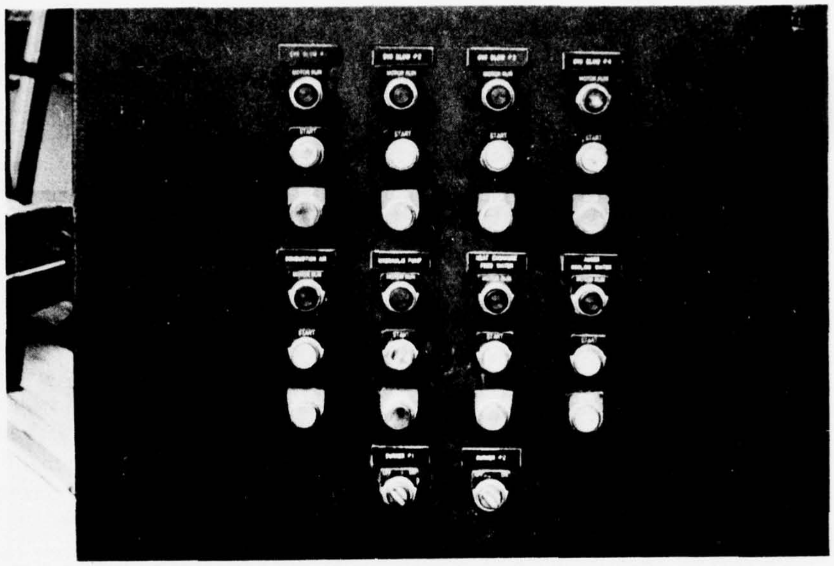

Figure 30. Display panel at operator station.

low and that the waste-to-steam conversion efficiency of the total ABI system is probably below 0.50. Improved engineering and design of the ABI system, such as putting a more reliable heat exchanger (e.g., water-tube boiler) in series with the furnace, would increase its conversion efficiency substantially.

Environmental Aspects

Environmental aspects of the prototype ABI focused on the unit's potential impact on air, land, and water resources. Potential plant environment (worker hazard) problems were also addressed.

Stack particulate emission sampling conducted according to EPA Method 5 by Technical Services Inc. (TSI) showed a concentration ranging from 0.2685 to 0.5030 grains/SCF (0.4940 mg/m^3) at 12 percent CO_2. Appendix A contains the TSI stack test report. The data indicate that the ABI will not comply with emission standards of 0.12 grains/SCF (0.22 mg/m^3). However, numerous control devices are currently marketed which could reduce particulate emissions to an amount well within existing standards.

Potential effects of the ABI on land resources were assessed from the standpoint of landfilling bypass wastes, ash, and residue from the ash pit air pollution control equipment. Bulk reduction of input waste to the furnace was approximately 80 percent. When bypass wastes are considered, every unit of delivered waste will be reduced in bulk by 72 to 78 percent. Improved system engineering and size reduction of bypass combustibles to permit their incineration would increase achievable bulk reduction. The mass reduction capabilities of the furnace appeared to be approximately 60 to 75 percent. Flies swarming both near the ash conveyor and the ash pile indicated the presence of organics. Moreover, at startup, the initial feed material would enter the ash quench in a charred rather than burned-out condition. Thus, the ABI would not produce a sterile or inert ash, but rather one which was considerably reduced in putrescibility; however, this is not unusual for any solid waste incinerator.

Table 3 summarizes an elemental analysis conducted by the University of Illinois Institute for Environmental Research on samples of scrubber sludge and ash. Of the 30 elements for which the investigation was conducted, lead, manganese, barium and chromium were detected in relatively high concentrations. Many compounds of these elements are toxic, as indicated in Table 3. These data underscore the necessity to use caution when

Table 3
Elemental Analysis of Scrubber Sludge and Ash

Element	Scrubber Sludge	Ash	Toxicity
Concentration in 10^{-9} grams/gram (ppb)			
Europium	0.67	0.43	Unknown
Lanthanum	22.00	8.03	Toxic
Bromine	45.25	164.75	Toxic
Arsenic	6.83	7.65	Toxic
Antimony	75.50	55.63	Toxic
Gallium	13.25	9.00	Moderately Toxic
Cerium	64.50	29.78	Safe
Ytterbium	0.72	2.65	Unknown
Barium	789.50	706.50	Toxic
Tantalum	1.85	19.23	Unknown
Lutetium	0.35	7.75	Safe
Selenium	3.53	33.50	Toxic
Mercury	0.07	0.02	Toxic
Terbium	0.79	0.27	Unknown
Thorium	13.78	5.33	Toxic
Chromium	630.75	690.00	Toxic
Hafnium	9.60	6.08	Toxic
Strontium	132.25	118.00	Moderately Toxic
Neodymium	33.25	18.33	Moderately Toxic
Zirconium	503.50	156.50	Safe
Cesium	0.53	0.68	Unknown
Manganese	222.75	815.00	Toxic
Scandium	8.62	4.15	Unknown
Rubidium	12.45	30.50	Metal Toxic
Cobalt	35.88	260.75	Safe
Lead	897.25	2522.50	Toxic
Concentration in Weight Percent			
Sodium	1.40	3.33	Metal Toxic
Potassium	0.67	0.28	Metal Toxic
Calcium	11.83	14.35	Safe
Iron	3.00	9.93	Dust Toxic

*General toxicities reported in N. Sax, *Dangerous Properties of Industrial Materials*, (Van Nostrand Reinhold Company, 1975). Specific toxicity depends on concentration, mode of ingestion, etc.

planning and carrying out landfill disposal of ash and residue.

During the test period, the ABI operated for 37 out of the planned 96 hours, thus having a reliability factor of 0.39. Although better design would increase the unit's reliability, a factor of 1.00 would be unrealistic. Unless redundant processing capability is installed in a plant using the ABI, landfill backup for semi-active ash and possibly bypass wastes will be necessary. The ash will have only 20 percent of the bulk of as-collected waste, perhaps adding to the functional life of the backup landfill.

Observations during the test suggest that water treatment before discharge will be necessary. Scrubber effluent was acidic (pH ranging between 2.0 and 3.5) and would hence require chemical treatment for neutralization. The biochemical oxygen demand of the scrubber water was not determined, but the captured residue did contain organic material, as evidenced by the presence of flies on a 10-lb (4.5-kg) sample collected and placed in an exposed area during the test period. It is expected that heavy metals in the ash quench will be of sufficient concentration to require removal before discharge of the effluent. Judging from the frequent presence of incompletely burned putrescible wastes in the quench, substantial cleanup of this water will be required. The pH in the ash quench was not determined.

Two aspects of the in-plant environment were briefly appraised. First, surface temperatures at 16 points in the ABI system were measured with a contact pyrometer. Appendix C presents raw data and a measurement location key. The data indicate that the highest surface temperatures were at the inlet ducts to the air pollution control equipment (680°F [360°C]), the outlet ducts from the air pollution control equipment (420°F [216°C]), and the rear of the unit at the inspection door (280°F [138°C]). Furnace shell temperatures averaged approximately 170°F (77°C), with a high of 245°F (118°C) recorded at the midpoint of the primary combustion zone. The occurrence of high surface temperatures represents a hazard to personnel that could be effectively dealt with by good plant design practice. The second aspect of the in-plant environmental analysis was noise. Appendix B provides raw data and a location key of noise measurements made during the test. Highest noise levels were measured between cyclones No. 2 and No. 3 on the loading end of the stack base (92 dBA) and along the side of the furnace (94 dBA). As with high surface temperatures, noise is a hazard to operating personnel. Proper design of the ABI, particularly in an enclosure, would reduce this hazard.

3 CONCLUSIONS

The innovative furnace in the prototype ABI evaluated for this study demonstrated short-term successful operation, processing up to 3.5 tons/hour (3.2 mt/hour) of solid waste, more than three times the throughput capability of currently marketed modular solid-waste incinerators.

With its existing configuration, materials of construction, and mechanical auxiliaries, the prototype ABI cannot be considered commercial, and hence cannot be recommended for immediate deployment to process waste generated at Army fixed facilities and installations.

It was evident during the field evaluation that the weaknesses of the prototype plant could be re-engineered using established methods to produce a more practicable, reliable, and efficient heat recovery incineration system to economically process installation solid waste.

4 RECOMMENDATIONS

It is recommended that the modular ABI concept be re-engineered and demonstrated for use in processing installation solid waste.

CITED REFERENCES

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Report on Status of Technology in the Recovery of Resources from Solid Wastes (Sanitation Districts of Los Angeles County, CA, 1976).

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APPENDIX A: STACK PARTICULATE EMISSIONS REPORT BY TECHNICAL SERVICES INC. (TSI)

1 INTRODUCTION

Source particulate emission testing was performed on the outlet stack of the Hoskinson Auger Combustor in Jacksonville, FL. This device is an incinerator of novel design.

The EPA Method 5 sampling train (see Chapter 5 of this appendix) was used in the testing. Integrated bag samples were taken on the scrubber inlet and outlet during each of the three particulate runs.

Mr. Roger Pfaff of the Environmental Protection Agency was present during the first day's testing.

2 SUMMARY AND DISCUSSION OF RESULTS

Results of the testing are summarized in Table A1. Complete emission data are located in Annex 1. Emission data, field data sheets, laboratory analyses, and instrument calibration data are furnished in Annexes 1, 2, 3, and 4, respectively.

Because the source is controlled by wet scrubbers, integrated bag samples were taken at the scrubber inlets and outlet simultaneously. This was done to credit the client with any possible CO_2 absorption of the scrubber water, as outlet grain loadings must be corrected to 12 percent CO_2. Before the inlet CO_2 value can be used, however, a correction must be made for the excess air differences of the inlet and outlet. This was done using the Excess Air (E.A.) Correction Factor of Table A1. Results of the second run proved to be higher using the factor and the inlet CO_2 reading of that run, than results using the outlet CO_2 value. The value listed is a corrected value based on the outlet CO_2 value.

Allowable emissions for incinerators are .08 grains per standard cubic foot corrected to 12 percent CO_2 stack gas constituent. On this basis, the source fails to meet peak emission standards. The low CO_2 values encountered are a result of excess air that is pulled in at the rear of the incinerator prior to the control equipment.

The third test run was by far the best of the series. This was the only run that was made when the system was operating at conditions that approached the designer's criteria. Several problems had occurred during the other two test runs which were conducted soon after system startup.

Table A1
Emission Summary

Date	Run No.	% CO_2 Inlet	% CO_2 Outlet	% E.A. Inlet	% E.A. Outlet	E.A. Correction* Factor	Grains SCF	Grains/SCF** 12 % CO_2	Volumetric Flow SCFMD
5/24/77	1	5.0	2.9	104	125	1.21	0.1455	0.5030	8515
5/25/77	2	4.0	2.8	192	277	1.44	0.1087	0.4659	9642
5/26/77	3	6.2	6.0	90	88	1.00	0.1387	0.2685	8026
	Mean	5.1	3.9	129	163	1.27	0.1310	0.4125	8728

*Emission Correction Factor based on increase in outlet excess air calculated by using inlet CO_2 value and outlet O_2 value.

**Corrected to 12 percent CO_2, using scrubber inlet CO_2 value and E.A. Correction Factor, unless a lower number results from using outlet CO_2 value.

3 PROCESS DESCRIPTION AND OPERATION

The Hoskinson Auger Combustor is a municipal waste incinerator that has been recently developed. The refuse is pushed through the combustion area by a large screw. This screw is hollow and is provided with a water supply for heat protection. The perimeter of the screw fins is provided with holes from which combustion air is blown. When the material reaches the end of the incinerator, it is water-quenched and conveyed to waiting trucks or hoppers. Excess air is drawn through the refuse discharge end of the incinerator.

The unit tested is equipped with four cyclone collectors that have water sprays at the inlets. Each cyclone has a fan run by a 20 hp motor. Any or all of the separate cyclone systems can be operated at one time depending on load. Because excess air is drawn into the incinerator near the area of the cyclone collectors, the gases are somewhat diluted and the CO_2 content is reduced from that of the combustion chamber. A heat exchanger coil is located in the large stack prior to the cyclones. After the gases pass through the cyclone scrubbers they are discharged into a common discharge stack (see Chapter 4 of this appendix).

4 SAMPLING POINT LOCATION

The sampling point location and outlet duct schematic are given in Figure A1.

5 FIELD AND ANALYTICAL PROCEDURES

Sampling

The sampling apparatus consisted of the following:

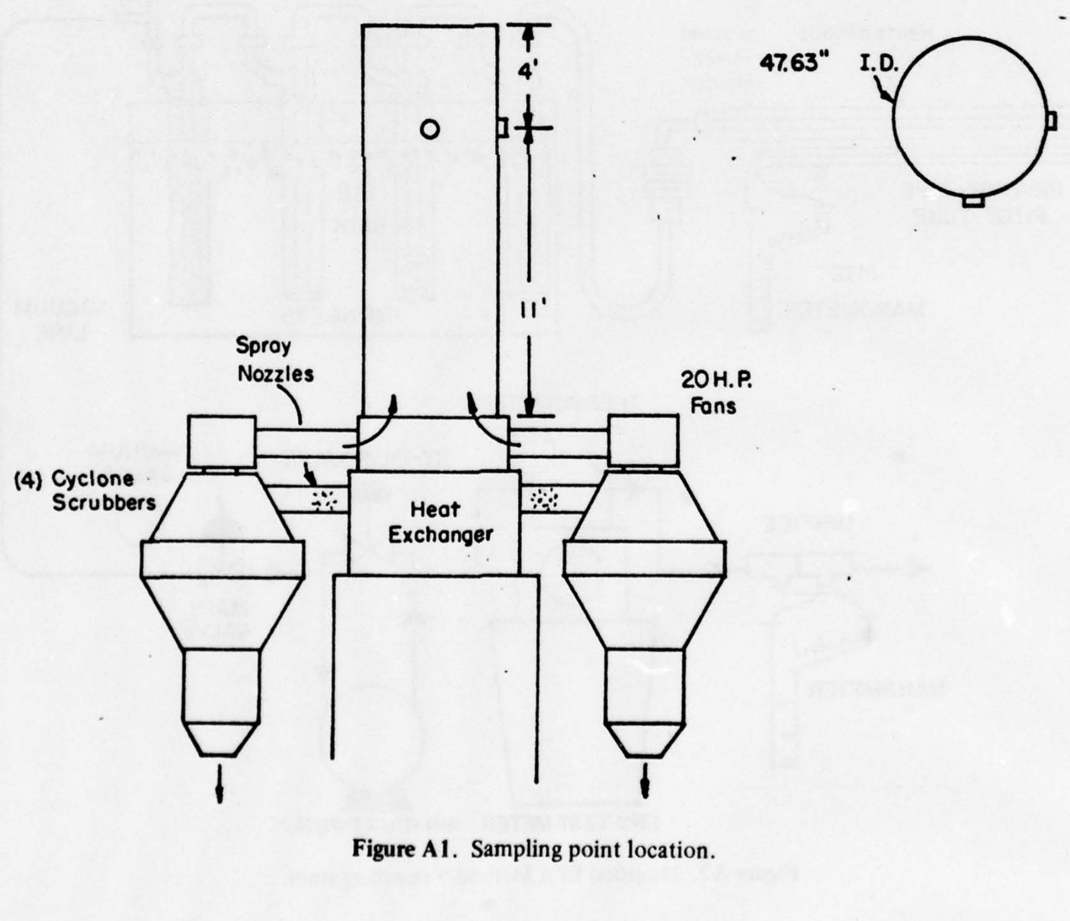


Figure A1. Sampling point location.

1. Nozzle – Stainless steel with a sharp, tapered leading edge.

2. Probe – Stainless steel sheath with a 5/8-in. O.D. Pyrex glass insert wrapped with asbestos-covered nichrome wire. Rheostat controlled and capable of maintaining a minimum temperature of 250°F.

3. Pitot – Type "S" attached to the probe.

4. Filter Holder – Pyrex glass with fritted glass filter support.

5. Impingers – Four impingers connected in series with glass ball joint fittings. The first, third, and fourth impingers are the modified Greenburg-Smith design. The second impinger is the Greenburg-Smith design with a standard tip.

6. Filter/Impinger Box – Aluminum module with heating system for maintaining the filter holder at a minimum temperature of 225°F for particulate sampling and an area for the impingers to be placed in an ice bath.

7. Control Box – Module containing vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within ±5°, dry gas meter with a minimum of 2 percent accuracy, valves and related equipment as required to maintain an isokinetic sampling rate and to determine sample volume.

8. Barometer – Aneroid type to measure atmospheric pressure to ±0.1 in. Hg.

A schematic of the sampling train is shown in Figure A2.

Prior to leaving the laboratory, glass fiber filters (type MSA 1106 BH) had been numbered for identification, desiccated for at least 24 hours, and preweighted to the nearest 0.1 mg. Silica gel (indicating type, 6-16 mesh)

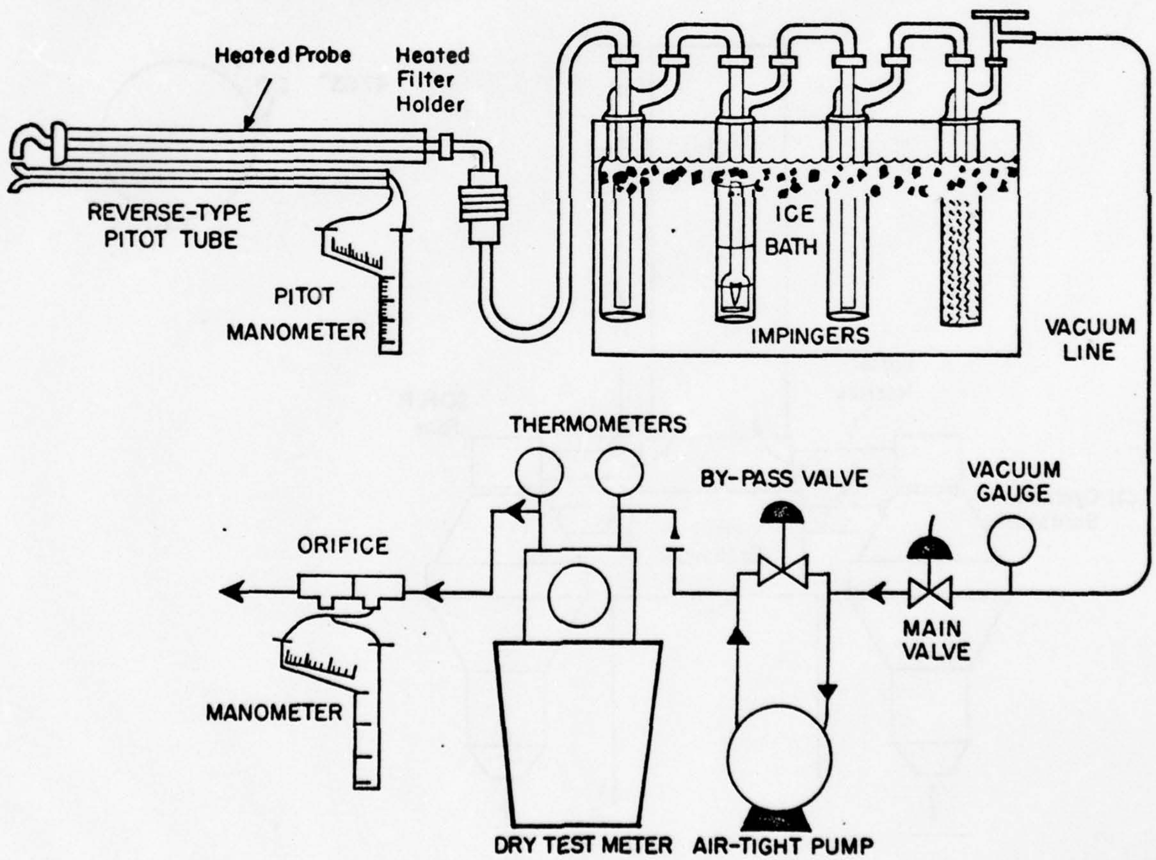


Figure A2. Modified EPA Method 5 sampling train.

had also been preweighed to approximately 200 g after drying at 175°F for 2 hours.

The sample train was prepared in the following manner: 100 mℓ of distilled water was added to each of the first two impingers. The third impinger was left empty to act as a moisture trap, and the pre-weighed silica gel was added to the fourth impinger. After assembling the train with the probe, as shown in the schematic, the system was leak checked by plugging the inlet to the probe nozzle and pulling a 15-in. Hg vacuum. A leakage rate not in excess of 0.02 cu ft/min was considered acceptable.

The inside dimensions of each stack were measured and recorded. The number of sampling points and the location of these points on a traverse were determined by the guidelines set forth in the *Federal Register*, Vol 36, No. 247, Sec. 60.85, Method 1. These points were then marked on the probe for easy visibility.

A preliminary traverse was conducted to determine the range of velocity head and the pressure of the stack. A wet bulb and a dry bulb temperature were taken to determine stack temperature and moisture. From these data, the correct nozzle size and the nomograph correction factor were determined.

The probe was attached and the heater was adjusted to provide a gas temperature of approximately 250°F. The filter heating system was turned on (during particulate sampling) and crushed ice was placed around the impingers. After a suitable warm-up period, the nozzle was placed on the first traverse point with the tip pointing directly into the gas stream. The pump was started immediately and the flow was adjusted to isokinetic conditions. After the required time interval had elapsed, the probe was repositioned to the next traverse point and isokinetic sampling was reestablished. This was done for each point on the traverse until the run was completed. Readings were taken at least every 5 min or when significant changes in stack conditions necessitated additional adjustments in flow rate. At the conclusion of each run, the pump was turned off and the final readings were recorded.

Particulate Sample Recovery

Care was exercised in moving the collection train to the sample recovery area to minimize the loss of collected sample or the gain of extraneous particulate matter. The volume of water in the first three impingers was measured and recorded on the field data sheet. The probe, nozzle, and all sample-exposed surfaces were washed with reagent grade acetone and put into a clean sample bottle marked "prefilter." A brush was used to loosen any adhering particulate matter and subsequent washings were put into the "prefilter" container. The filter was carefully removed from the fritted glass support and placed in a clean Petri dish marked "filter." This silica gel was removed from the fourth impinger and transferred to its original container. A sample of the acetone used in washing the probe was saved for a blank laboratory analysis.

Particulate Analytical Procedures

The filter and any loose particulate matter were transferred from the Petri dish to a clean, tared glass weighing dish. The filter was placed in a desiccator for at least 24 hours, dried to a constant weight and then weighed. The original weight of the filter was deducted and the weight gain was recorded to the nearest 0.1 mg.

The "prefilter" solution was transferred to a clean, tared beaker. The solution was evaporated to dryness, desiccated to a constant weight, and the weight gain was recorded to the nearest 0.1 mg. The silica gel was weighed and the weight gain was recorded to the nearest 0.1 gram.

Integrated Bag Sampling

Because allowable incinerator emissions are based on a grain loading corrected to 12 percent CO_2 content, an integrated bag gas sample by EPA Method 3 was made during each run at the cyclone scrubber inlets and at the outlet stack. The inlet sampling was done so that the client would be given credit for any CO_2 that might be absorbed by the scrubber water.

ANNEX 1: COMPLETE EMISSION DATA

Source Sampling Nomenclature Sheet

PB–Barometric pressure, in. Hg
PS–Stack pressure, in. Hg
As–Stack area, sq ft
AS′–Effective area of positive stack gas flow, sq ft
NPTS–Number of traverse points where the pitot velocity head was greater than zero
TS–Stack temperature, °R
TM–Meter temperature, °R
H–Average square root of velocity head, $\sqrt{\text{inches } H_2O}$
$\bar{H}$–Average meter orifice pressure differential, in. H_2O
AN–Sampling nozzle area, sq ft
CP–S-type pitot tube correction factor
VM–Recorded meter volume sample, cu ft (meter conditions)
VC–Condensate and silica gel increase in impingers, mℓ
Po–Pressure at the dry test meter orifice, $\left[PB + \frac{\Delta H}{13.6}\right]$ in. Hg
STP–Standard conditions, dry, 70°F, 29.92 in. Hg
VWV–Conversion of condensate in mℓ to water vapor in cu ft (STP)
VSTPD–Volume sampled, cu ft (STP)
VT–Total water vapor volume and dry gas volume sampled, cu ft (STP)
W–Moisture fraction of stack gas
FDA–Dry gas fraction
MD–Molecular weight of stack gas, lbs/lb-mole (dry conditions)
MS–Molecular weight of stack gas, lbs/lb-mole (stack conditions)
GS–Specific gravity of stack gas, referred to air
EA–Excess air, percent
$\sqrt{HxTS}$–Average square root of velocity head times stack temperature
$\bar{U}$–Stack gas velocity, ft/min
QS–Stack gas flow rate, cu ft/min (stack conditions)
QD–Stack gas flow rate, cu ft/min (dry conditions)
QSTPD–Stack gas flow rate, cu ft/min (STP)
PISO–Percent isokinetic volume sampled (method described in *Federal Register*)
ESTP–Particulate concentration at standard and dry conditions, grains/SCF
E_{12}–ESTP corrected to 12 percent CO_2, grains/SCF
E_{50}–ESTP corrected to 50 percent Excess Air, grains/SCF
EM–Mass Emission Rate, lbs/hour

Equations for Calculating Particulate Emissions

$$VWV = (0.0474) \times (VC)$$

$$VSTPD = (17.71) \times (VM) \times \left(PB + \frac{\Delta H}{13.6}\right) \div TM$$

$$VT = (VWV) + (VSTPD)$$

$$W = (VWV) \div (VT)$$

$$FDA = (1.0) - (W)$$

FMOIST = Assumed moisture fraction

$$MD = (0.44 \times \%\ CO_2) + (0.32 \times \%\ O_2) + (0.28 \times \%\ N_2) + (0.28 \times \%\ CO)$$

$$MS = (MD \times FDA) + (18 \times W)$$

$$GS = (MS) \div (28.99)$$

$$EA = \left[(100) \times \left(\%\ O_2 - \frac{\%\ CO}{2}\right)\right] \div \left[(0.266 \times \%\ N_2) - \left(\%\ O_2 - \frac{\%\ CO}{2}\right)\right]$$

$$\underline{U} = (174) \times (CP) \times (\underline{H}) \times \sqrt{(TS \times 29.92) \div (GS \times PS)}$$

$$QS = (\underline{U}) \times (AS)$$

$$QD = (QS) \times (FDA)$$

$$QSTPD = (530) \times (QD) \times (PS) \div TS \div 29.92$$

$$PISO = [(0.00267 \times VC \times TS) + (P_0 \times TS \times VM \div TM)] \div [(Time \times \underline{U} \times PS \times AN)]$$

$$ESTP = \frac{\left(\frac{15.43\ grains}{gram}\right)(y)}{VSTPD}$$

$$E_{12} = \frac{(ESTP)\ (12)}{(CO_2\ \%)}$$

$$E_{50} = \frac{(ESTP)\ (100 + EA)}{150}$$

$$EM = (ESTP)\ (QSTPD) \left(60\ \frac{min}{hr}\right)\left(\frac{lb}{7000\ grains}\right)$$

PLANT- GATEWAY INCINERATOR, JACKSONVILLE, FLA. DATE- 5/24/77
STACK- INCINERATOR OUTLET RUN 1 FROM 1505-1642
WEATHER CONDITIONS- CLOUDY PB- 30.19 IN HG PS-30.19 IN HG
AS'- 12.37 SQ. FEET TS- 858.3 DEGREES R TM- 567.8 DEGREES R
H- 0.303 IN H2O ΔH- 1.13 IN H2O AN- 0.000739 SQ FT CP- 0.814
VM- 56.365 CF VC- 174.1 ML TOTAL TIME- 96 MIN NPTS- 48
ORSAT: CO2- 2.90 02-14.90 CO- 0 N2-82.20

1.	Volume Water Vapor	1.	8.252	SCF
2.	Gas Volume Sampled – STPD	2.	53.029	SCFD
3.	Total Volume	3.	61.281	SCF
4.	Moisture in Stack Gas – Volume Fraction	4.	0.135	
5.	Dry Stack Gas – Volume Fraction	5.	0.865	
6.	Assumed Moisture in Stack Gas – Volume Fraction	6.	0.12	
7.	Molecular Weight of Stack Gas – Dry Basis	7.	29.06	
8.	Molecular Weight of Stack Gas – Stack Conditions	8.	27.57	
9.	Specific Gravity of Stack Gas Relative to Air	9.	0.95	
10.	Excess Air – Percent	10.	214	%
11.	Average of Factor ($\sqrt{H \times TS}$)	11.	8.863	
12.	Average Stack Velocity	12.	1281.5	FPM
13.	Actual Stack Gas Flow Rate	13.	15852	ACFM
14.	Actual Stack Gas Flow Rate Dry	14.	13717	CFMD
15.	Stack Gas Flow Rate – STPD	15.	8515	SCFMD
16.	Percent Isokinetic	16.	108.6	%

	MG	GR/SCF	GR/ACF	LBS/HR
FILTER –	397.9	0.1156	0.0624	8.45
PRE FILTER –	103.0	0.0299	0.0161	2.19
TOTALS –	500.9	0.1455	0.0785	10.64

Comments:

Tests Conducted by:

PLANT-GATEWAY INCINERATOR, JACKSONVILLE, FLA. DATE-5/24/77
STACK-INCINERATOR OUTLET RUN 2 FROM 1124-0845
WEATHER CONDITIONS-CLOUDY PB- 30.19 IN HG PS- 30.19 IN HG
AS - 12.37 SQ. FEET TS- 867.3 DEGREES R TM- 556.3 DEGREES R
H- 0.323 IN H2O ΔH- 1.17 IN H2O AN- 0.000739 SQ FT CP- 0.814
VM- 56.318 CF VC- 78.3 ML TOTAL TIME- 96 MIN NPTS- 48
ORSAT: CO2- 2.80 02-17.20 CO- 0 N2- 80

1.	Volume Water Vapor	1.	3.711	SCF
2.	Gas Volume Sampled – STPD	2.	54.091	SCFD
3.	Total Volume	3.	57.803	SCF
4.	Moisture in Stack Gas – Volume Fraction	4.	0.064	
5.	Dry Stack Gas – Volume Fraction	5.	0.936	
6.	Assumed Moisture in Stack Gas – Volume Fraction	6.	0.13	
7.	Molecular Weight of Stack Gas – Dry Basis	7.	29.14	
8.	Molecular Weight of Stack Gas – Stack Conditions	8.	28.42	
9.	Specific Gravity of Stack Gas Relative to Air	9.	0.98	
10.	Excess Air – Percent	10.	422	%
11.	Average of Factor (H × TS)	11.	9.522	
12.	Average Stack Velocity	12.	1356	FPM
13.	Actual Stack Gas Flow Rate	13.	16773	ACFM
14.	Actual Stack Gas Flow Rate Dry	14.	15696	CFMD
15.	Stack Gas Flow Rate – STPD	15.	9642	SCFMD
16.	Percent Isokinetic	16.	97.8	%

	MG	GR/SCF	GR/ACF	LBS/HR
FILTER –	276.1	0.0786	0.0454	6.51
PRE FILTER –	105.6	0.0301	0.0174	2.49
TOTALS –	381.7	0.1087	0.0628	9.00

Comments:

Tests Conducted by:

PLANT-GATEWAY INCINERATOR, JACKSONVILLE, FLA. DATE-5/24/77
STACK-INCINERATOR OUTLET RUN 3 FROM 0947-1120
WEATHER CONDITIONS-CLOUDY PB- 30.03 IN HG PS- 30.03 IN HG
AS - 12.37 SQ. FEET TS- 912.3 DEGREES R TM- 549.7 DEGREES R
H- 0.31 IN H2O ΔH- 1.08 IN H2O AN- 0.000739 SQ FT CP- 0.814
VM- 55.01 CF VC- 242.8 ML TOTAL TIME- 96 MIN NPTS- 48
ORSAT: CO2- 6 02-13.00 CO- 0 N2- 81

1.	Volume Water Vapor	1.	11.509	SCF
2.	Gas Volume Sampled – STPD	2.	53.174	SCFD
3.	Total Volume	3.	64.682	SCF
4.	Moisture in Stack Gas – Volume Fraction	4.	0.178	
5.	Dry Stack Gas – Volume Fraction	5.	0.822	
6.	Assumed Moisture in Stack Gas – Volume Fraction	6.	0.12	
7.	Molecular Weight of Stack Gas – Dry Basis	7.	29.48	
8.	Molecular Weight of Stack Gas – Stack Conditions	8.	27.44	
9.	Specific Gravity of Stack Gas Relative to Air	9.	0.95	
10.	Excess Air – Percent	10.	152	%
11.	Average of Factor (H × TS)	11.	9.35	
12.	Average Stack Velocity	12.	1358.8	FPM
13.	Actual Stack Gas Flow Rate	13.	16808	ACFM
14.	Actual Stack Gas Flow Rate Dry	14.	13817	CFMD
15.	Stack Gas Flow Rate – STPD	15.	8026	SCFMD
16.	Percent Isokinetic	16.	115.5	%

	MG	GR/SCF	GR/ACF	LBS/HR
FILTER –	352.0	0.1019	0.0489	7.03
PRE FILTER –	127.0	0.0368	0.0176	2.54
TOTALS –	479.0	0.1387	0.0665	9.57

Comments:

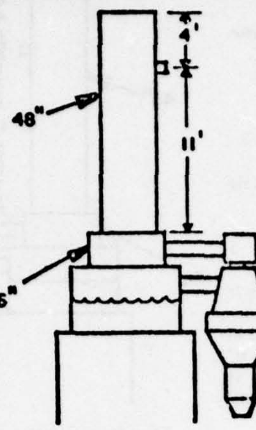
Tests Conducted by:

ANNEX 2:
FIELD DATA SHEETS

Source Sampling Field Data Sheet

Plant Gateway Incinerators
Jacksonville, Florida
Sample Location Incinerator Outlet
Control Device 4 wet cyclones

Type of Samples Particulate
Date 5-24-77 Run No. 1
Moisture 12%, FDA , Gas Density Factor
Barometric Press 30.9 in. Hg, Stack Press in.Hg
Weather Cloudy
Temp. °F, W/D , W/S
Sample Box No. Meter Box No. 5
Meter ΔH@ 1.90 Pitot Corr. Factor 814
Nozzle Dia. .368 in., Probe Length 7 ft
Probe Heater Setting
Stack Dimensions: Inside Diameter 4763 in
Inside Area ft²
Height ft
Effective Stack Area 1237 ft² 48 pts.



Time Start 1505
Time End 1642
@ 2 min/pt = 96 min.

Mat'l Processing Rate
Final Gas Meter Reading 132.745 ft³
Initial Gas Meter Reading 76.380 ft³
Total Condensate in Impingers 161 ml
Moisture in Silica Gel 13.1 gm
Silica Gel Container No. Filter No.

Orsat: CO_2	5.0	4.2	4.2	4.2
O_2	11.0	14.0	14.1	14.1
CO	0	0	0	0
N	0	2.9	2.9	2.9
	14.9	14.9	14.9	
Excess Air	0	0	0	

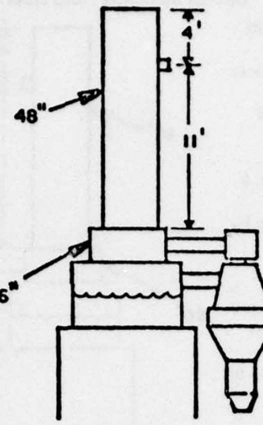
Test Conducted by: Neck-Kimball
Leak Rate 0.00 CFM @ 15 in. Hg
Remarks: 2 cyclones
3 cyclones for 1/4 of run

Port And Traverse Point No.	Inches Inside Stack Wall	Clock Time	Gas Meter Reading (ft³)	Stack Velocity Head (in.H2O)	("H2O) Orifice Press. Calc.	Drop Actual	Stack Gas Temp. (°F)	Meter Temperature In	Out	Filter Temp. (°F)	Last Impinger Temp.(°F)	Vacuum ("HG)
1- 1		1505	77.21	.04	.52	.52	379	100	101	275		3½
2			78.02	.04	.52	.52	362	100	101			
3			78.80	.04	.52	.52	364	100	101			
4			79.63	.045	.58	.58	384	100	101			
5			80.50	.045	.58	.58	396	101	101			
6		1575	81.38	.05	.65	.65	387	102	102			
7			82.25	.05	.61	.61	379	102	102			
8			-	.055	.67	.67	376	103	102			
9			84.10	.06	.73	.73	376	104	102			
10			85.14	.07	.88	.88	370	106	103			
1-11		1525	86.33	.095	1.18	1.8	375	106	103			5
12			87.52	.09	1.10	1.10	374	108	104	275		
13			88.68	.09	1.10	1.10	384	108	104			
14				.085	1.04	1.04	400	108	104			
15			90.98	.085	1.04	1.04	400	109	104			
16		1535	92.13	.085	1.04	1.04	409	109	104			
17			93.30	.09	1.1	1.1	408	109	104	250	68	
18			94.52	.095	1.18	1.8	428	109	104			
19			95.76	.10	1.22	1.22	423	109	104	255		
20			97.00	.105	1.3	1.3	429	108	104			
21		1545	98	.105	1.3	1.3	438	108	104			
22				.105	1.2	1.2	456	108	104	265	68	7
23			100.73	.105	1.2	1.2	468	108	104			
24		1551	101.95	.105	1.2	1.2	454	108	104			
2- 1		1556	103.2	.09	1.1	1.1	423	108	106	260	68	7
2			104.4	.09	1.1	1.1	423	109	106			
3		1600	105.5	.09	1.1	1.1	432	110	107	260	68	7
4			106.7	.09	1.1	1.1	432	110	107			
5			108.0	.10	1.22	1.22	436	111	107	260	68	7
6		1606	109.3	.10	1.22	1.22	444	111	107			
7			110.5	.10	1.2	1.2	432	112	108	260	68	7
8		1610	111.5	.11	1.22	1.22	443	113	108			
9			112.9	.11	1.22	1.22	443	113	108			
10				.12	1.45	1.45	441	115	109	260	68	8
11		1616	115.5	.12	1.45	1.45	430	117	110			
12			117.0	.12	1.45	1.45	421	117	110			
13			118.3	.12	1.45	1.45	410	117	110			
14			119.7	.10	1.20	1.22	409	117	110	260	68	8
15		1624	120.8	.11	1.22	1.22	404	117	110			
16			122.1	.12	1.45	1.45	376	117	110			
17			123.6	.12	1.45	1.45	366	116	110			
18			124.6	.12	1.45	1.45	350	116	110	260	68	8
19			126.0	.12	1.45	1.45	346	116	110			
20		1634	127.3	.125	1.47	1.47	340	116	110			
21			128.7	.125	1.47	1.47	345	116	110	260	68	9
22			129.9	.12	1.45	1.45	315	116	110			
23			131.3	.12	1.45	1.45	315	116	110			
24		1642	132.745	.12	1.45	1.45	327	115	110			

Source Sampling Field Data Sheet

Plant Gateway Incinerators
Jacksonville, Florida
Sample Location Incinerator Outlet
Control Device 4 wet cyclones

Type of Samples Particulate
Date 5-25-77 Run No. 2
Moisture 13%, FDA , Gas Density Factor
Barometric Press 30.19 in. Hg, Stack Press in.Hg
Weather Clear
Temp. °F, W/D , W/S
Sample Box No. Meter Box No. 5
Meter ΔH@ 190 Pitot Corr. Factor .815
Nozzle Dia. .368 in., Probe Length 6 ft
Probe Heater Setting
Stack Dimensions: Inside Diameter 47.63 in
Inside Area ft³
Height ft
Effective Stack Area 12.37 ft² 48 pts.



Time Start 1124
Time End 0845
@ 2 min/pt = 96 min.

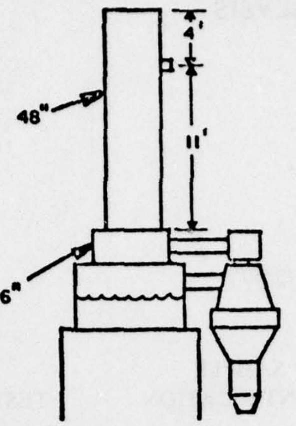
Mat'l Processing Rate
Final Gas Meter Reading 189.50 ft³
Initial Gas Meter Reading 133.185 ft³
Total Condensate in Impingers 65 ml
Moisture in Silica Gel 13.3 gm
Silica Gel Container No. Filter No.
Orsat:
CO_2 4.0 4.1 4.0 2.8 2.9 2.8
O_2 15.9 15.9 16.0 17.2 17.2 17.2
CO
N_2
Excess Air
Test Conducted by:
Neck-Kimball-McKee-Mims
Leak Rate 0.00 CFM @ 15 in. Hg
Before and After
Remarks:

Port And Traverse Point No.	Inches Inside Stack Wall	Clock Time	Gas Meter Reading (ft³)	Stack Velocity Head (in.H2O)	("H2O) Press. Calc.	Orifice Drop Actual	Stack Gas Temp. (°F)	Meter Temperature In	Meter Temperature Out	Filter Temp. (°F)	Last Impinger Temp.(°F)	Vacuum ("HG)
1- 1		1126	134.1	.09	1.0	1.0	398	91	93	250	68	4
2			135.4	.09	1.0	1.0	398	91	93			
3		1130	136.5	.09	1.0	1.0	400	93	93			
4			137.5	.10	1.1	1.1	400	94	94			
5		1134	138.6	.10	1.1	1.1	424	95	94			
6			139.8	.10	1.1	1.1	424	96	94			
7		1138	141.1	.10	1.1	1.1	434	98	95	250	68	5
8			142.0	.10	1.1	1.1	435	98	95			
9		1148	143.0	.10	1.1	1.1	435	98	95			
10			144.2	.10	1.1	1.1	435	100	96			
1-11		1146	145.6	.10	1.1	1.1	447	103	96	260	68	5
12			146.7	.10	1.1	1.1	443	103	96			
13			148.1	.09	1.0	1.0	443	103	97			
14		1152	149.2	.09	1.0	1.0	437	103	98			
15			150.5	.10	1.1	1.1	429	103	98			
16			151.3	.10	1.1	1.1	429	103	98	270	68	6
17		1158	152.5	.10	1.1	1.1	429	103	98			
18				.11	1.25	1.25	423	105	100			
19			154.9	.11	1.25	1.25	426	105	100			
20			156.1	.12	1.35	1.35	426	105	100			
21		1206	157.3	.12	1.35	1.35	426	107	100	270	68	8
22				.14	1.60	1.60	406	108	102			
23			160.2	.14	1.60	1.60	397	110	103			
24		1212	161.6	.14	1.60	1.60	397	110	103			
2- 1		1216	162.9	.10	1.1	1.1	372	108	104	250	68	7
2			164.0	.10	1.1	1.1	372	108	104			
3			164.8	.09	1.0	1.0	380	109	105			
4		1222	165.6	.09	1.0	1.0	380	109	105			
5			167.1	.09	1.0	1.0	386	109	105			
6			168.4	.09	1.0	1.0	386	110	105	250	65	8
7		1228	169.5	.09	1.0	1.0	390	110	105			
8				.09	1.0	1.0	398	110	105			
9			171.7	.09	1.0	1.0	398	110	106			
10			173.0	.10	1.1	1.1	398	110	106			
11		1236	174.0	.10	1.1	1.1	350	110	106			
12			175.4	.10	1.1	1.1	350	110	106	250	68	8
13			176.4	.10	1.1	1.1	340	110	106			
14			177.4	.10	1.1	1.1	340	110	106			
15		1244	178.75	.10	1.1	1.1	340	110	106			
16			179.88	.10	1.1	1.1	420	68	68	275	60	
17			181.04	.11	1.22	1.22	420	69	68			
18			182.20	.11	1.22	1.22	415	70	68			
19		0835	183.37	.12	1.35	1.35	430	72	68			
20			184.56	.12	1.35	1.35	430	73	68			
21			185.79	.13	1.46	1.46	427	74	69			
22			187.05	.13	1.46	1.46	424	75	69	270	62	8
23			188.26	.13	1.46	1.46	429	76	69			
24		0845	189.50	.13	1.46	1.46	425	77	70			

Source Sampling Field Data Sheet

Plant Gateway Incinerators
Jacksonville, Florida
Sample Location Incinerator
Outlet Stack
Control Device 4 wet
cyclones

Type of Samples Particulate
Date 5-26-77 Run No. 3
Moisture 12%, FDA , Gas Density Factor
Barometric Press 30.03 in. Hg
Stack Press 30.05 in. Hg
Weather Clear
Temp. °F, W/D , W/S
Sample Box No. Meter Box No. 5
Meter $\Delta H@$ 190 Pitot Corr. Factor 814
Nozzle Dia. .368 in., Probe Length ft
Probe Heater Setting
Stack Dimensions: Inside Diameter 4763 in
Inside Area ft²
Height ft
Effective Stack Area 12.37 ft² 48 pts.



Mat'l Processing Rate
Final Gas Meter Reading 244.59 ft³
Initial Gas Meter Reading 189.58 ft³
Total Condensate in Impingers 231 ml
Moisture in Silica Gel 12.8 gm

Orsat:	Inlet			Outlet		
CO_2	6.2	6.2	6.1	6.0	6.0	6.0
O_2	13.2	13.1	13.2	13.0	13.0	12.9
CO	0	0	0			
N_2						
Excess Air						

Test Conducted by:
Neck-Mims-Kimball
Leak Rate 000 CFM @ 15 in. Hg
Remarks:

Time Start 0947
Time End 1120
@ 2 min/pt = 96 min.

Port And Traverse Point No.	Inches Inside Stack Wall	Clock Time	Gas Meter Reading (ft³)	Stack Velocity Head (in.H2O)	("H2O) Orifice Press. Calc.	Drop Actual	Stack Gas Temp. (°F)	Meter Temperature In	Out	Filter Temp. (°F)	Last Impinger Temp.(°F)	Vacuum ("HG)
1- 1		1049	190.82	.11	1.26	1.26	358	76	76	260	64	5
2			192.08	.11	1.26	1.26	358	76	76			
3			193.33	.11	1.26	1.26	371	78	76			
4			194.52	.11	1.26	1.26	384	78	76	245		5
5			195.75	.11	1.26	1.26	384	80	77		65	
6			198.98	.11	1.26	1.26	417	84	77			
7			198.25	.11	1.26	1.26	422	84	77			
8			199.41	.11	1.26	1.26	415	85	78			
9			-	.10	1.14	1.14	436	86	78	255	65	5
10			206.90	.10	1.14	1.14	445	87	80			
1-11			203.17	.10	1.14	1.14	445	88	80			
12			204.34	.10	1.14	1.14	426	89	80	260		6
13			205.50	.10	1.14	1.14	432	89	81			
14			206.65	.10	1.14	1.14	444	90	82			
15			207.83	.10	1.14	1.14	442	91	83	260	66	6.5
16			209.00	.10	1.14	1.14	437	92	84			
17			210.19	.10	1.14	1.14	448	92	84	250	66	6.5
18			211.36	.10	1.14	1.14	425	92	84			
19			212.58	.11	1.26	1.26	420	92	85			
20			213.80	.11	1.26	1.26	428	93	86	250	67	7.0
21			215.03	.11	1.26	1.26	428	94	86			
22			216.24	.11	1.26	1.26	412	94	86			
23			217.46	.11	1.26	1.26	400	95	86			
24			218.14	.10	1.14	1.14	410	95	87	255	67	7.5
2- 1		1034	219.65	.07	.82	.82	415	92	88	260	67	6.0
2			220.62	.07	.82	.82	410	93	88			
3			221.72	.09	1.05	1.05	440	93	88	260	67	7.0
4			222.81	.08	.94	.94	459	93	88			
5			223.88	.08	.94	.94	481	94	89	255	67	7.0
6			224.99	.09	1.05	1.05	487	94	89			
7			226.13	.09	1.05	1.05	486	95	89			8.0
8			227.21	.08	.94	.94	507	95	90			
9			228.30	.09	.96	.96	504	96	90	255	68	7.5
10			229.37	.09	.96	.96	494	96	90			
11			230.42	.08	.86	.86	505	96	91			
12			231.49	.09	.96	.96	516	98	92			
13			232.53	.08	.86	.86	516	98	92			
14			233.54	.08	.86	.86	520	98	92	255		8.0
15			234.57	.08	.86	.86	515	99	93			
16		1104	235.59	.08	.86	.86	522	99	94			
17			236.62	.08	.86	.86	514	101	95			
18			237.71	.09	.96	.96	502	101	95			
19			238.84	.10	1.06	1.06	489	102	96	250	68	9.0
20			239.98	.10	1.06	1.06	491	103	96			
21			241.16	.11	1.19	1.19	475	103	97			
22			242.32	.10	1.06	1.06	486	104	97			
23			243.46	.10	1.06	1.06	494	104	97			
24		1120	244.59	.10	1.06	1.06		105	98	255	68	10.0

ANNEX 3: LABORATORY ANALYSIS

PLANT Gateway

LOCATION

STACK

DATE SAMPLED 5/24/77

LAB. NUMBER	SAMPLE IDENTIFICATION		TEST	METHOD	RESULTS
20948	Filter	Run 1	Particulate		0.3979
	Pre Filter	Run 1	Particulate		0.1030
20948	Filter	Run 2	Particulate		0.2761
	Pre Filter	Run 2	Particulate		0.1056
20948	Filter	Run 3	Particulate		0.3520
	Pre Filter	Run 3	Particulate		0.1270

Silica

Moisture	4.1 g
Run 1	13.1 g
Run 2	13.3 g
Run 3	12.0 g

PLANT & LOCATION Gateway

STACK DATE 5/24/77 ANALYST Ernest Ducanay

20948

FILTERS	RUN 1	RUN 2	RUN 3
Sample No.			
Filter No.	53837	53921	53922
Beaker & Filter Weight	96.7080	92.4666	93.4135
Beaker Tare Weight	95.9188	91.8002	92.6667
Gross Gain	0.7892	0.6664	0.7468
Filter Tare Weight	0.3913	0.3903	0.3948
Net Gain (grams)	0.3979	0.2761	0.3520

FILTERS			
Sample No.			
Filter No.			
Beaker & Filter Weight			
Beaker Tare Weight			
Gross Gain			
Filter Tare Weight			
Net Gain (grams)			

SAMPLE ID			
Sample No.			
Sample Volume	470 cc	162 cc	206 cc
Aliquot	235 cc	81 cc	103
Factor	2	2	2
Final Weight	95.3684	90.9658	96.8239
Tare Weight	95.3169	90.9130	96.7604
Net Gain	0.0515	0.0528	0.0635
Net Gain × Factor = Total (grams)	0.1030	0.1056	0.1270

SAMPLE ID			
Sample No.			
Sample Volume			
Aliquot			
Factor			
Final Weight			
Tare Weight			
Net Gain & Factor = Total (grams)			

ANNEX 4:
CALIBRATION DATA

METER CALIBRATION FORM

Date April 14, 1977

Box No. 5 Barometric Pressure 29.95 Inches Hg

		Gas Volume, Wet Gas Meter			Gas Volume, Dry Gas Meter					
ΔHW	ΔHD	Initial	Final	Actual ft^3	Initial	Final	Actual ft^3	Temperature of Wet Meter	Temperature of Dry Meter	Time Minutes
0.3	0.5	0.00	3.932	3.932	789.338	793.299	3.961	74.5	79	10
0.6	1.0	3.932	9.512	5.580	793.299	798.929	5.630	74.5	82	10
0.8	2.0	9.512	3.338	3.826	798.929	802.829	3.890	74.5	86	5
1.2	3.0	3.338	7.894	4.556	803.819	807.486	4.667	74.5	85	5

ΔH = 1.816987944 1.797093124 1.899122247 2.01659135
MEAN = 1.882448666
Y = 0.9990723783 1.001088004 0.9978361851 0.9852045269
MEAN = 0.9958002736
SCFM = 0.3861604824 0.5443094375 0.7391472371 0.8796423446

PITOT TUBE CALIBRATION

DATE: 4-27-77

TUBE DESIGNATION: #4

	Test No. 1 Forward	ΔP Reverse	Test No. 2 Forward	ΔP Reverse	Test No. 3 Forward	ΔP Reverse
Standard Pitot	.51	.51	.51	.51	.51	.51
S-Type Pitot	.76	.75	.76	.75	.76	.75

$C_{P1} = .814$

$C_{P2} = .814$

$C_{P3} = .814$

$C_P = .814$

$$C_P = 0.99 \sqrt{\frac{\Delta P \text{ Standard}}{\Delta P \text{ S-Type}}}$$

APPENDIX B: ACOUSTIC DATA RECORDED BY CERL

Noise levels at selected locations at the ABI plant were recorded on a Model 1565-13 General Radio Company Sound Level Meter, using A-scale* slow response. Table B1 provides the locations of measurement points, which are mapped in Figure B1. Table B2 provides raw data recorded during eight measurements taken during the ABI test period. Background noise was uniformly less than 50 dBA. Highest noise levels were recorded near the stack at approximately 20 ft (6.1 m) from the operator station (Point 6) and at two points along the side of the units (Points 15 and 16). High noise levels at these locations were due largely to inadequate motor housing. During the test it was observed that noise levels at the operator station (Point 5) jumped from approximately 83 dBA to more than 95 dBA when waste fell into the loading end of the furnace. Such levels are legally tolerable only 4 hours/day, so it is doubtful that the ABI operator would be in an acoustically safe environment. Installation of the plant in an enclosure would require improved unit construction and perhaps other sound-reducing measures to insure a safe working environment.

*The A-weighted sound level is a single number measure of the magnitude of a noise signal with a weighting characteristic which de-emphasizes the low frequency portion of the noise spectrum to approximate the response of the human ear.

Table B1
Description of Noise Measurement Locations

1. 85 ft (26 m) from right edge of unit along main axis
2. 60 ft (18 m) from right edge of unit along main axis
3. 40 ft (12 m) from right edge of unit along main axis
4. 5 ft (2 m) from right edge of unit along main axis, 2 ft (.6 m) offset to center
5. At operator controls/station
6. At scrubber/stack, front on platform
7. 20 ft (6 m) from right side facing No. 3 scrubber
8. 40 ft (12 m) from right side facing No. 3 scrubber
9. Working trailer entrance, 110 ft (34 m) from rear center of unit
10. 100 ft (30 m) along rear centerline
11. 50 ft (15 m) along rear centerline
12. Rear of delivery pit
13. 30 ft (9 m) from left, between scrubbers No. 1 and No. 2
14. 5 ft (2 m) from left, between scrubbers No. 1 and No. 2
15. 2 ft (0.6 m) between scrubbers No. 3 and No. 4
16. 2 ft (0.6 m) above motor on right of unit
17. Corner of construction building 120 ft (37 m) from center rear of unit
18. Against fence, 100 ft (30 m) from center of unit, to right.

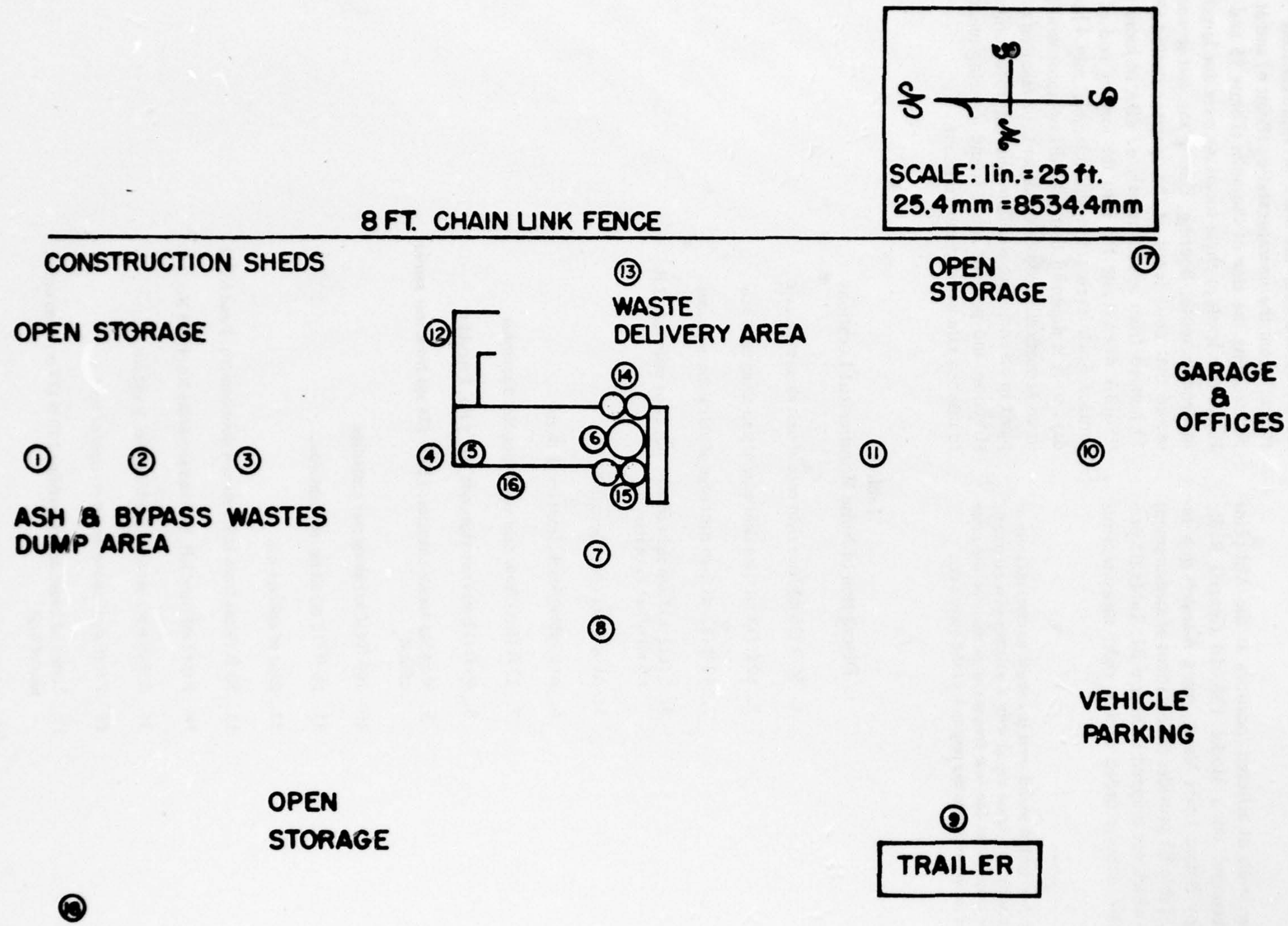


Figure B1. Locations of noise measurement stations.

Table B2
Noise Data Recorded by CERL (dBA)

Measurement Station	24 May 0800-0830 Background	24 May 1045-1110	24 May 1520-1540	24 May 1840-1910	25 May 1050-1110	26 May 1200-1220	26 May 1755-1805	26 May 2300-2325	Average	Standard Deviation
1	<50	68	68	68	69	71	70	69	69	1.2
2	<50	72	71	71	71	73	75	71	72	1.5
3	<50	74	72	73	73	77	76	76	74	2.0
4	<50	79	78	79	79	81	81	78	79	1.3
5	<50	83	89	80	81	82	82	81	83	3.0
6	<50	91	88	90	92	92	92	91	91	1.5
7	<50	81	80	80	82	83	81	81	81	1.1
8	<50	78	78	78	80	81	79	79	79	1.2
9	<50	<50	73	77	76	76	74	75	72	9.6
10	<50	<50	69	69	72	70	68	70	67	7.5
11	<50	<50	73	74	76	76	74	73	71	9.3
12	<50	74	73	79	76	76	78	77	76	2.1
13	<50	76	77	78	80	82	82	80	79	2.4
14	<50	54	81	82	85	82	82	83	78	10.9
15	<50	58	85	87	94	92	86	88	84	11.2
16	<50	56	92	92	92	92	90	91	86	13.4
17	<50	67	67	69	67	68	68	68	68	0.8
18	<50	71	69	66	72	72	72	71	70	2.2

APPENDIX C: SURFACE TEMPERATURE DATA RECORDED BY CERL

Surface temperatures were recorded by an ALnor "Thermocon" contact pyrometer. Table C1 lists the measurement locations, which are mapped in Figure C1. Table C2 furnishes raw data recorded during the field test. Highest temperatures were recorded on inlet and outlet ducts to the air pollution control equipment (Stations 2 and 4). Temperatures here were as high as 680°F (360°C). Measurements on the rear inspection door were as high as 280°F (138°C), which presents a definite hazard to personnel. Temperatures on the furnace shell were sufficiently low to present no apparent hazard to the plant. Proper design of equipment (e.g., facing ductwork with refractory) will reduce surface temperatures and their attendant hazards. Nonetheless, if the ABI is installed in an enclosure, sufficient ventilation and air circulation should be provided to vent heat from the plant.

Table C1
Temperature Measurement Locations

1. Base of stack along unit centerline, 1 ft (0.3 m) above platform/heat exchanger
2. On duct to No. 2 scrubber inlet, before water spray
3. Wall of Scrubber No. 2
4. Outlet duct from Scrubber No. 2
5. Center of rear hatch
6. Outlet of No. 4 scrubber outlet, 1 ft (0.3 m) above ash hatch
7. Rear side of ash conveyor housing, center
8. Side opposite point H

A.
B.
C.
D.
E.
F.
G.
H.

Uniformly spaced from loading to discharge end at half elevation

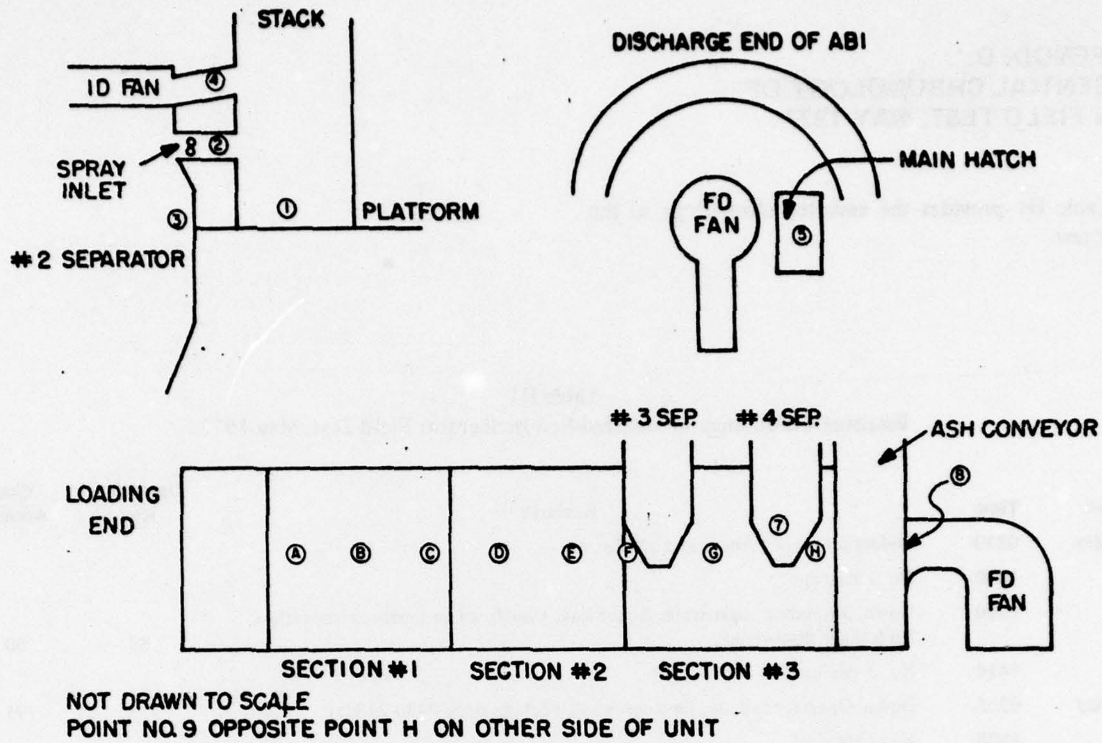


Figure C1. Location of surface temperature measurements.

Table C2
Surface Temperature Data Recorded by CERL (°F)*

Measurement Station	24 May 1115-1130	24 May 1655-1715	24 May 2000-2125	25 May 1115-1130	26 May 1100-1120	26 May 1735-1750	26 May 2330-2355
Cold Junction	84	84	83	84	78	81	73
1	92	200	200	120	200	150	220
2	510	540	600	640	680	540	510
3	150	140	170	155	150	135	145
4	330	312	420	405	380	290	305
5	260	280	190	280	275	180	200
6	122	120	140	130	145	135	120
7	88	100	95	100	125	95	90
8	80	130	95	105	140	147	150
A	–	120	205	127	140	190	225
B	–	155	205	132	130	190	210
C	86	165	200	132	130	180	200
D	–	185	235	139	155	220	245
E	–	190	240	139	150	220	235
F	–	185	210	139	140	190	230
G	–	170	205	137	135	180	215
H	–	129	170	115	125	120	130

*To obtain degrees centigrade, use $°C = \frac{(5 \times °F) - 160}{9}$

APPENDIX D: ESSENTIAL CHRONOLOGY OF ABI FIELD TEST, MAY 1977

Table D1 provides the essential chronology of the field test.

Table D1
Essential Chronology of Augered-Bed Incinerator Field Test, May 1977

Date	Time	Remarks	Operating Run	Mins. Accum.
24 May	0830	Preinspection of furnace and auxiliaries.		
	1040	No. 1 startup.		
	1200	Down. Suspected auger water jacket leak. Cooldown and manual inspection. No leakage discovered.	80	80
	1410	No. 2 startup.		
25 May	0205	Down. Operator fatigue. Two operators working since 0430 24 May.	715	795
	1020	No. 3 startup.		
	1240	Down. Main drive sprocket mounting bolts sheared when auger reversed to remove air or vapor lock. Sprocket removed. Rewelding.	140	935
	1415	No. 4 startup.		
	1615	Down. Air or vapor lock remains in auger water jacket. Cooldown. Auger reversed to remove trap when main sprocket repaired.		
	1640	Continued down. Auxiliary drive sprocket failure; knocked to offset position when main drive sprocket removed earlier. Welding to realign front drive system.	120	1055
26 May	0550	No. 5 startup.		
	1200	Down. Ash conveyor jammed with wire. Manual cleanout initiated before cooldown. Welder used to remove wire twisted around edge of auger shaft. Jam-up apparently due to bedspring present at ash conveyor exit from rear quench.	370	1425
	1310	No. 6 startup.		
	1450	Down. Diesel-powered front-end loader mistakenly refilled with gasoline. Gas being purged from engine and tank. Diesel refilled.	100	1525
	1620	No. 7 startup.		
	1800	Down. Ash conveyor broken. Rusted link failed. Rewelding.	100	1625
	1905	No. 8 startup.		
27 May	0505	Down. Operator fatigue. Ash quench left activated when two operators retired. At 0800, furnace flooded with 1 ft (.3 m) water. Hole torched in lower front wall to assist drainage of unit; plugged with waste. Test discontinued; estimated 5 hours minimal adequate cleanup/restart time required.	600	2225*
	0825	Post-operational inspection of furnace and auxiliaries.		
	1015	Post-test meeting with contractor to review work performance.		
	1245	Packed equipment and left site.		

*Total operating hours: 2225 ÷ 60 = 37.1.

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